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DRAFT

BIOVENTING TEST WORK PLAN AND INTERIM RESULTS REPORT FOR THREE BIOVENTING SITES PATRICK AIR FORCE BASE AND CAPE CANAVERAL AIR FORCE STATION, FLORIDA

ES ENGINEERING-SCIENCE

Prepared For

Air Force Center for Environmental Excellence
Brooks AFB, Texas

and

45 CES/DEEV
Patrick Air Force Base, Florida

Engineering-Science, Inc.
255 SOUTH ORANGE AVENUE, SUITE 1201
ORLANDO, FLORIDA 32801

June 1993

AOM01-C4-0653

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ES
ENGINEERING-SCIENCE, INC.

1700 BROADWAY
SUITE 900
DENVER, COLORADO 80290
TEL: (303) 831-8100
FAX: (303) 831-8208

10 June 1993

Captain Chung Yen
AFCEE/ESCT
8001 Inner Circle Drive, Suite 2
Brooks AFB, Texas 78235-5000

RE: Draft Bioventing Test Work Plan and Interim Test Results Report for Patrick AFB, Florida; Cape Canaveral AFS, Florida

Dear Captain Yen:

Enclosed is the Draft Bioventing Test Work Plan and Interim Test Results Report for Firefighter Training Area FTA-2, Cape Canaveral Air Force Station; Fire Fighter Training Area FTA-2, and the BX Service Station, Patrick Air Force Base, Florida. This draft interim report describes the site-specific implementation of the Test Work Plan and initial testing results for each site. In general, the results were very positive with excellent oxygen distribution in these sandy soils.

ES understands that Patrick AFB and Cape Canaveral AFS will obtain regulatory approval prior to ES conducting the extended pilot tests at these sites. If you have any questions concerning the initial results or future testing schedule, please call me at (303) 831-8100 or Steve Archabal at (407) 841-8114.

Sincerely,

ENGINEERING-SCIENCE, INC.

Douglas C. Downey, P.E.
Project Manager

Enclosure

c.c.: Mr. Hugh Houghton, Patrick AFB/Cape Canaveral AFS

PART IA & IB

Draft Test Work Plan
For Three Bioventing Sites

Cape Canaveral AFS, Florida
and
Patrick AFB, Florida

Prepared for:

Air Force Center for Environmental Excellence
Brooks AFB, Texas

and

45 CES/DEEV
Patrick AFB, Florida

Prepared by:

ENGINEERING SCIENCE, INC.

255 South Orange Avenue, Suite 1201
Orlando, Florida

January 1993

PART IA

Draft Test Work Plan

For Site FTA-2
Patrick AFB, Florida

CONTENTS

FIGURES

DRAFT

BIOVENTING TEST WORK PLAN FOR FIRE PROTECTION TRAINING AREA (FTA) 2 PATRICK AFB, FLORIDA

1.0 INTRODUCTION

This site-specific work plan presents the scope of multiphase bioventing pilot tests for *in situ* treatment of fuel-contaminated soils at the Fire Protection Training Area designated as Site FTA-2 at Patrick Air Force Base (AFB), Florida. The proposed pilot tests will be performed by Engineering-Science, Inc. (ES). The three primary objectives of the proposed pilot tests are: 1) to assess the potential for supplying oxygen throughout the contaminated soil depth, 2) to determine the rate at which indigenous microorganisms will degrade the fuel when stimulated by oxygen-rich soil gas, and 3) to evaluate the potential for sustaining these rates of biodegradation until fuel contamination is remediated to concentrations below regulatory standards.

If bioventing proves to be a feasible technology for this site, pilot test data may be used to design a full-scale remediation system and to estimate the time required for remediating soils to regulatory standards. An added benefit expected from the pilot testing at the Site FTA-2 area is that a significant amount of the fuel contamination should be biodegraded during the 1-year pilot test, as the testing will take place within the most contaminated soils that have been detected at the site.

The pilot tests will utilize one horizontal air injection vent well (HVW) and a blower capable of sustaining a flow rate of 20 to 40 standard cubic feet per minute (scfm). Vertical air injection vent well tests typically produce an effective radius of influence of approximately 20 to 40 feet. As is expected at Site FTA-2, HVWs placed in areas with a shallow water table may have reduced effective radii of influence. The design air injection rate and actual radius of influence for this site will depend on soil properties and other factors. Rates of *in situ* fuel biodegradation will be determined for individual soil vapor monitoring points (VMPs) that will be installed around the HVW.

Additional background information on the development and recent success of the bioventing technology is found in the document entitled *Test Plan and Technical Protocol For A Field Treatability Test For Bioventing* (Hinchee et al., 1992). This protocol document is a supplement to the site-specific work plan and it will also serve as the primary reference for pilot test HVW and VMP designs and detailed

test objectives and procedures. Unless otherwise noted, test procedures outlined in the protocol document will be used during the pilot test at Site FTA-2.

2.0 SITE DESCRIPTION

2.1 Site Location and History

Site FTA-2 is located west of Building 685 and approximately 100 feet east of the Banana River on Patrick AFB (Figure 2.1). Site FTA-2 consists of an unlined, earth-bermed circular burn pit approximately 2 feet in depth and 150 feet in diameter. The bermed area was used from 1963 to 1985 for fire control training exercises. A variety of combustible wastes (e.g., contaminated fuels and waste oils) were burned at the site until 1978, after which only uncontaminated fuels were used. No containment system was used to prevent direct infiltration of fuel into the soils.

A Phase II study conducted in 1990 indicated that total recoverable petroleum hydrocarbons (TRPH) were detected at a maximum concentration of 38,200 milligrams per kilogram (mg/kg) in soil samples from borings drilled at the site (O'Brien & Gere Engineers, Inc., 1990). The significant hydrocarbon soil contamination found at this site is the primary target for bioventing treatment.

2.2 Site Geology

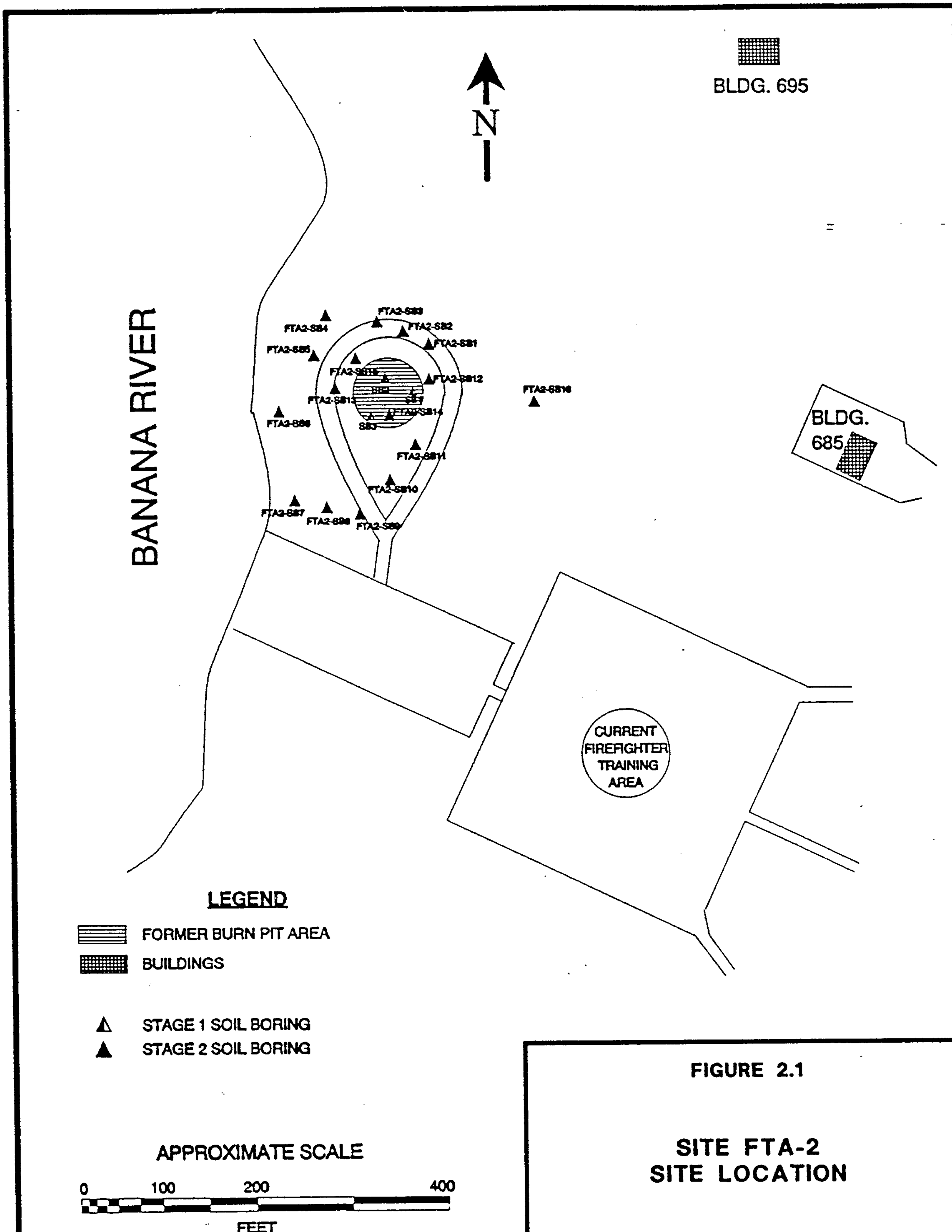
Because the bioventing technology is applied to the unsaturated soils, this section will primarily address soils above the shallow aquifer. Soils at this site and to a depth of 36 feet below ground surface consist of predominantly unconsolidated, moderately well-sorted, fine- to medium-grained quartz sand with 5 to 40 percent shells and shell fragments. Ground water is encountered at fluctuating depths of approximately 3 to 5 feet. The generally homogeneous, sandy material at this site appears to be well suited to bioventing treatment.

2.3 Site Contaminants

The primary contaminants at Site FTA-2 are petroleum hydrocarbons, which have been detected in the soils above the shallow aquifer. A maximum TRPH concentration of 38,200 mg/kg has been detected in a surface soil sample. Samples from the 1990 soil borings drilled inside the pit area and above the aquifer showed TRPH concentrations from 9.83 mg/kg to 16,700 mg/kg; most values were in the several thousand mg/kg range. Volatile organic compounds benzene, toluene, ethylbenzene, and total xylenes (BTEX) were detected in both soil and ground water at the site. Traces of several chlorinated solvents have also been detected in soil and ground water (O'Brien & Gere Engineers, Inc., 1990).

3.0 PILOT TEST ACTIVITIES

The purpose of this section is to describe the proposed location of a central HVW and five vapor monitoring locations at Site FTA-2. Soil sampling procedures and the blower configuration that will be used to inject air (oxygen) into contaminated soils also are discussed in this section. Pilot test activities will target unsaturated soils. The 4-inch air injection well will not be completed into the ground water, and no dewatering will take place during the pilot tests. Existing monitoring wells will not be used as primary air injection or vapor monitoring wells. However, existing uncontaminated monitoring wells that have a portion of their



SOURCE: O'BRIEN & GERE ENGINEERS, INC.

26827-02, 10/14/92 at 08:53

FIGURE 2.1

SITE FTA-2
SITE LOCATION

Patrick AFB, Florida

ENGINEERING-SCIENCE, INC.

Denver, Colorado

screened interval above the water table may be used to measure the composition of background soil gas. If an existing background monitoring well does not meet this criteria, then a background MP will be installed.

3.1 Bioventing Test Design For Site FTA-2

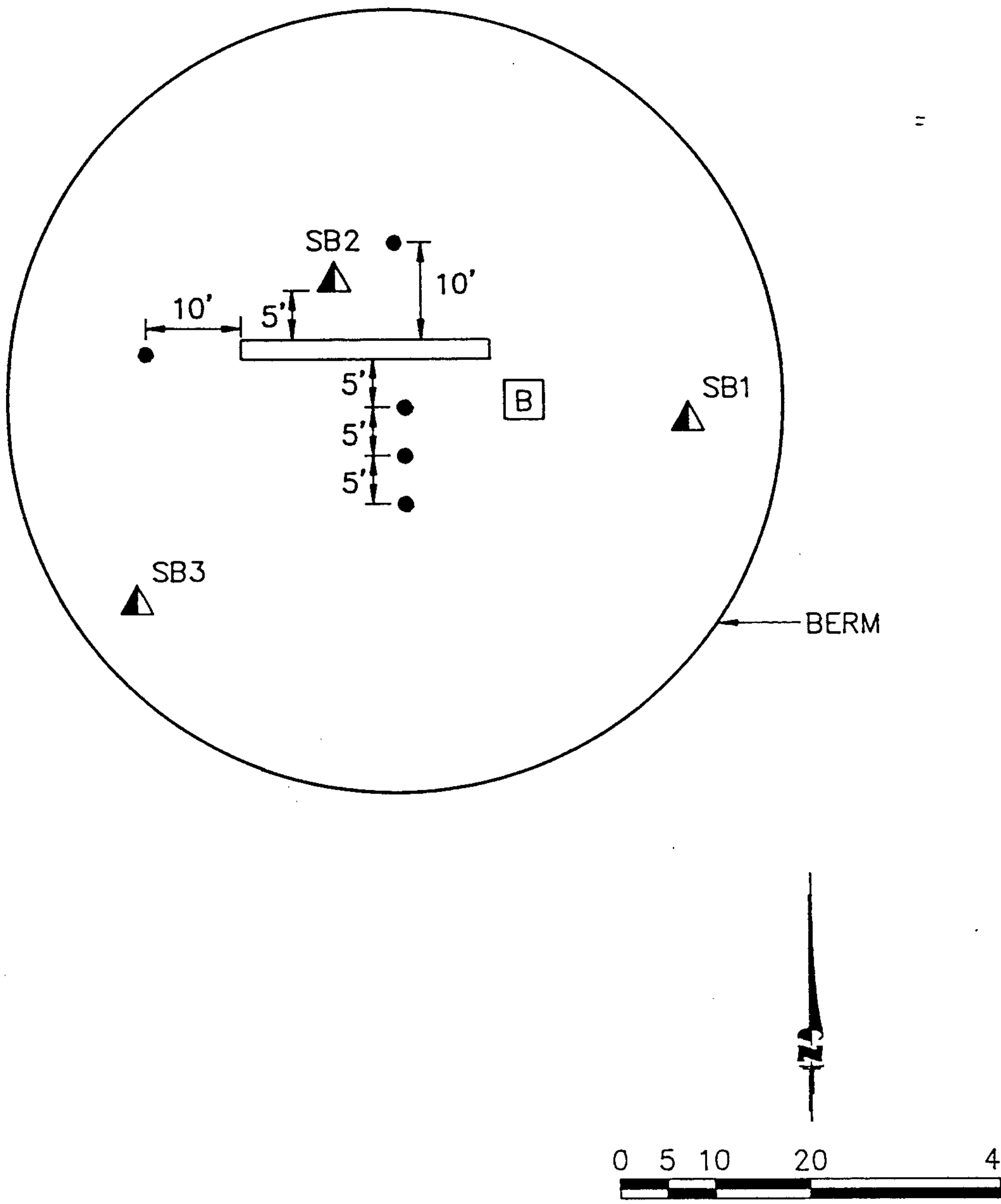
A general description of criteria for siting a central HVW and VMPs are included in the protocol document. Figure 3.1 illustrates the proposed locations of the HVW and VMPs at the site. The HVW will be installed in a narrow trench excavated in contaminated soils just above the water table. Wherever possible, the trench will be located in the area of highest surface relief. Orientation of the trench axis is expected to be approximately east-west, in the most contaminated soil interval at the site. Five VMPs will be placed at varying distances from the trench. The final locations of the VMPs may vary slightly from the locations shown in Figure 3.1 if significant fuel contamination is not observed in the boring for the first VMP.

Based on site investigation data, the central HVW should be located in close proximity to existing borehole SB2. This area is expected to have an average TRPH concentration exceeding 5,000 mg/kg in unsaturated soils. Soils in this area have the greatest potential of being oxygen depleted (<2%), and increased biological activity should be stimulated by oxygen-rich soil gas ventilation during pilot test operations.

Considering the shallow depth of contamination in unsaturated soils at this site (<5 feet below ground surface), the soil lithology, and the horizontal design configuration of the air injection well required to accommodate shallow water table conditions, the radius of venting influence around the central HVW is expected not to exceed 15 feet. A primary concern at this site is possible short-circuiting of injected air to the ground surface, resulting in a loss of the effective radius of venting influence. The installation of an HVW with a bentonite seal above the trench is expected to minimize this effect, and will likely produce better test results than a vertical vent well design.

Five VMPs will be located within a 15-foot radius of the central HVW (Figure 3.1). An effort will be made to use an existing well to measure background levels of oxygen and carbon dioxide in soil vapor and to determine if natural carbon sources (i.e., organic layers) or chemical reactions are contributing to oxygen uptake during the *in situ* respiration test. If no suitable existing well is available, a background VMP will be constructed. Additional details on the *in situ* respiration test are found in Section 5.7 of the protocol document (Hinchee et al., 1992).

The central HVW will be constructed of 4-inch inside-diameter Schedule 40 polyvinyl chloride (PVC), with 20 feet of 0.03-inch slotted screen set in a narrow trench at approximately 4.5 feet below ground surface. A 5-foot PVC casing will extend horizontally beyond the screened section, followed by a PVC elbow and a 4-inch vertical PVC riser pipe. Flush-threaded PVC casing and screen with no organic solvents or glues will be used. A filter pack of coarse silica sand will be placed entirely around the screened interval in the form of a gravel envelope. The trench will then be backfilled with the excavated residual soil and compacted to increase the soil density of this zone. The top 1 foot of the trench excavation will be



LEGEND

BLOWER AND INJECTION TRENCH

SOIL VAPOR MONITORING POINTS

SB3 EXISTING SOIL BORINGS

26827-05, 10/14/92 at 10:00

FIGURE 3.1

SITE FTA-2
BIOVENTING PILOT TEST
SITE PLAN

Patrick AFB, Florida

ENGINEERING-SCIENCE, INC.

Denver, Colorado

completed with a soil/bentonite mixture overlain by a layer of bentonite. Powdered bentonite will also be applied to the surface soils in a rectangular surface cap extending at least 5 feet beyond the perimeter of the trench. A complete surface seal is necessary in order to prevent injected air from short-circuiting to the surface during the bioventing test. Figure 3.2 illustrates the proposed HVW construction for this site.

A typical multi-depth VMP installation design for this site is shown in Figure 3.3. Soil gas oxygen and carbon dioxide concentrations will be monitored at depth intervals of 1.5 to 2.5 feet and 4 to 5 feet at each location. Multi-depth monitoring will confirm that the entire soil profile is receiving oxygen, and will be used to measure fuel biodegradation rates at both depths. The annular space between these two monitoring points will be sealed with bentonite to isolate the monitoring intervals. Data from the background VMP will also be used to determine the relative natural diffusion of atmospheric oxygen into the shallow soils. Additional details on VMP construction can be found in Section 4 of the protocol document.

3.2 Handling of Soil Boring Cuttings and Excavated Soils

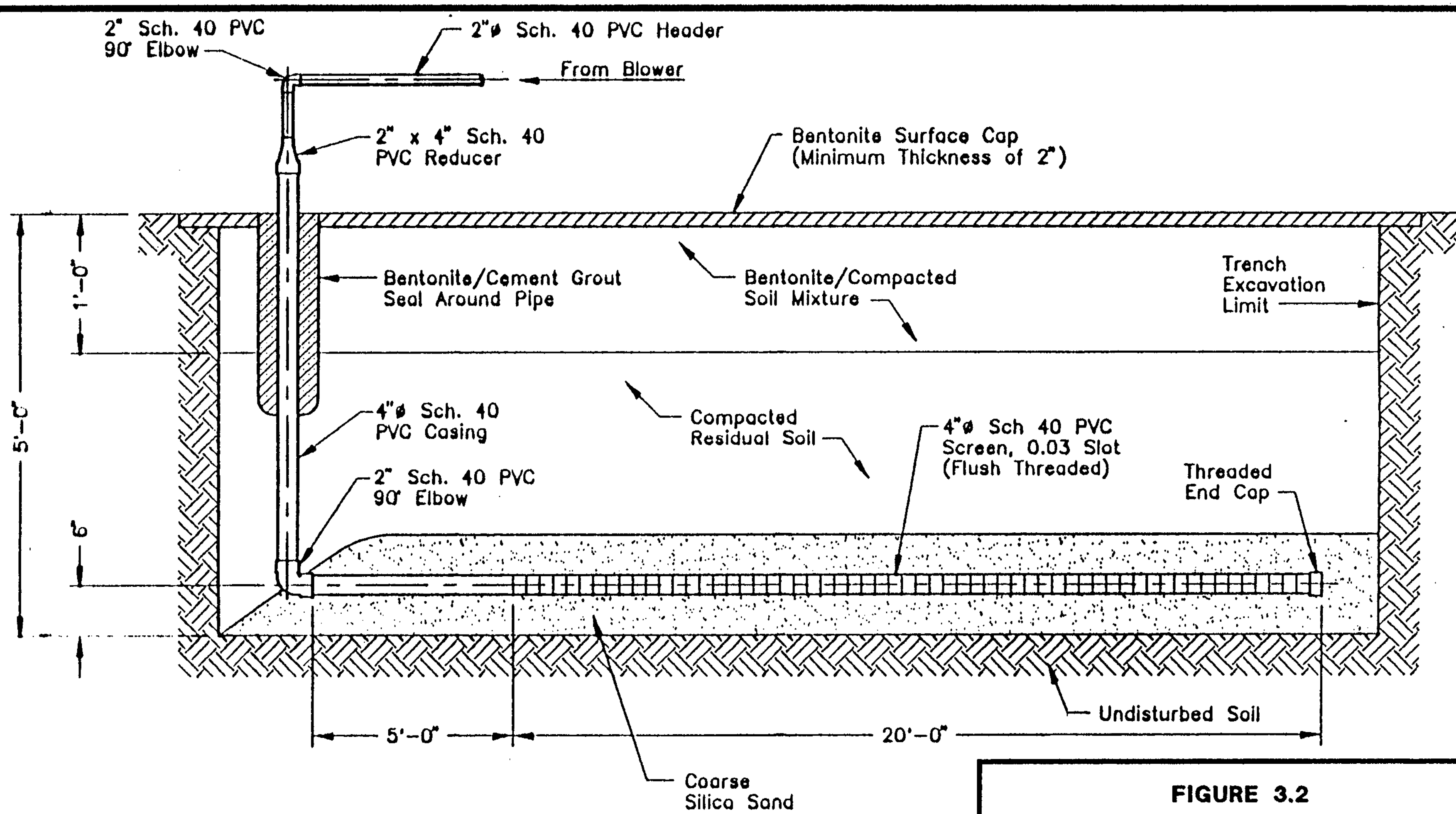
Cuttings from all soil borings and any remaining waste soils from trench excavation will be collected in a Department of Transportation (DOT) approved container. The containers will be labeled and then placed in a designated Patrick AFB hazardous materials storage area. These waste soils will become the responsibility of Patrick AFB, and will be analyzed, handled, and disposed of in accordance with the current procedures for ongoing remedial investigations. This project is expected to generate less than two 55-gallon drums of cuttings.

3.3 Soil and Soil Gas Sampling

3.3.1 Soil Sampling

Three soil samples will be collected from the pilot test area during the installation of the HVW and VMPs. Sampling procedures will follow those outlined in the protocol document, with minor modifications for collection of one sample from the most contaminated interval of the HVW trench. One sample will be collected from the interval of highest apparent contamination in two of the borings for the VMPs. Soil samples will be analyzed for TRPH, BTEX, soil moisture, pH, particle sizing, alkalinity, total iron, and nutrients.

Samples will be collected by hand augering to the desired sampling depth and then driving by hand either a small-diameter Shelby® tube or a split-spoon device equipped with a sampling sleeve. A photoionization detector or total hydrocarbon vapor analyzer (see protocol document Section 4.5.2.) will be used to ensure that breathing-zone levels of volatiles do not exceed 1 part per million, per volume (ppmv) while conducting soil borings and trench excavation, and to screen split-spoon samples for intervals of high fuel contamination. Soil samples collected in the tubes will be immediately trimmed, and aluminum foil and a plastic cap will be placed over the ends. Soil samples will be labeled following the nomenclature specified in the protocol document (Section 5.5), wrapped in plastic, and placed in an ice chest maintained at a temperature of 4° Centigrade for shipment. A chain-of-custody form will be filled out, and the ice chest shipped to the ES laboratory in Berkeley, California for analysis. This laboratory has been audited by the U.S. Air



Notes:

1. Drawing is not to scale.
2. All fittings must be flanged or screwed type.

FIGURE 3.2

SITE FTA-2
PROPOSED INJECTION VENT WELL AND TRENCH CONSTRUCTION

Patrick AFB, Florida

ENGINEERING-SCIENCE, INC.
Denver, Colorado

26827-03, 10/14/92 at 09:03

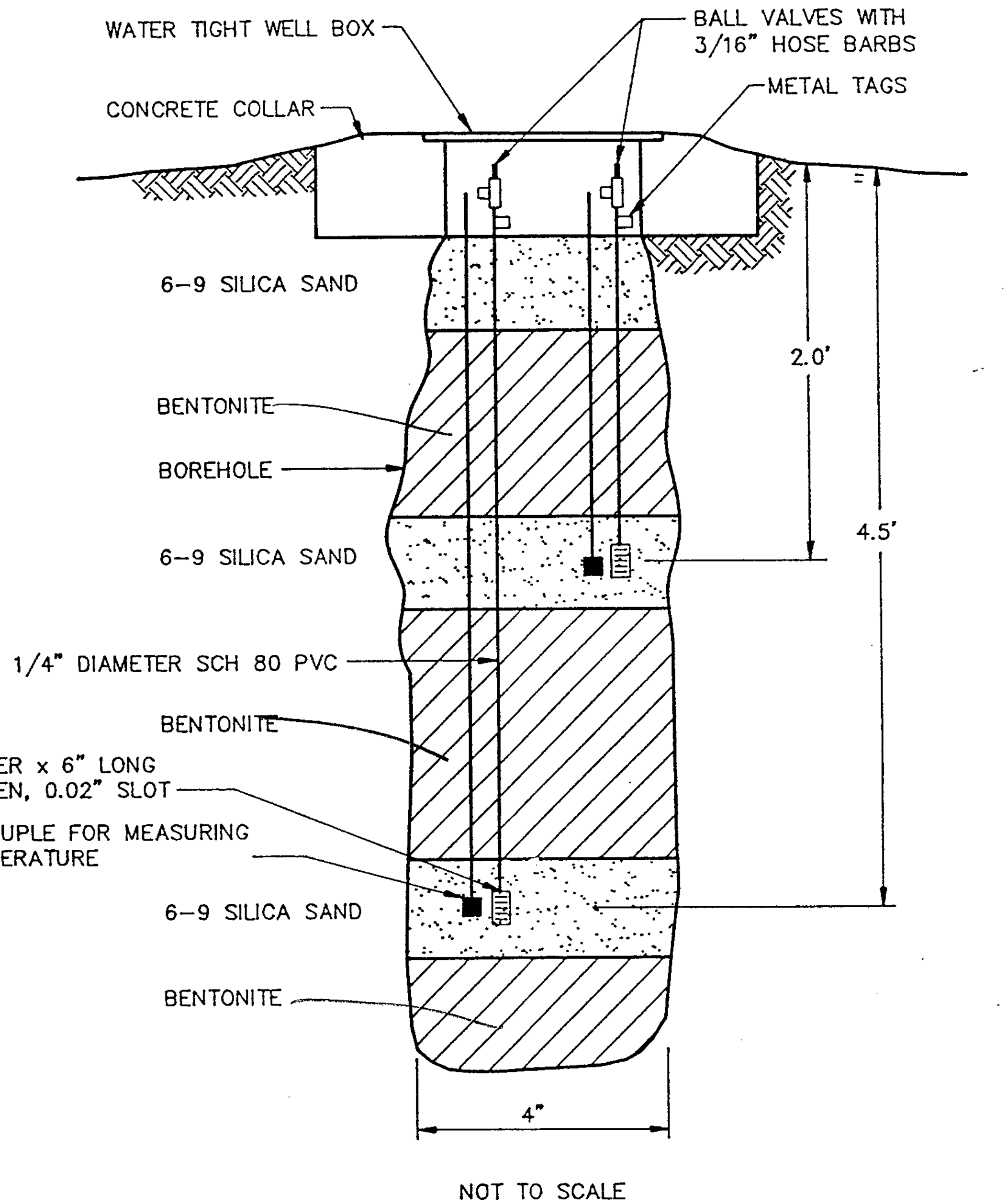


FIGURE 3.3

MONITORING POINT CONSTRUCTION DETAIL

Patrick AFB, Florida

ENGINEERING-SCIENCE, INC.

Denver, Colorado

26827-01, 10/16/92 at 14:51

Force and meets all quality assurance/quality control and certification requirements for the State of California.

3.3.2 Soil Gas Sampling

A total hydrocarbon vapor analyzer will be used during augering to screen split-spoon soil samples for intervals of high fuel contamination. Initial soil gas samples will be collected in SUMMA® cannisters in accordance with the *Bioventing Field Sampling Plan* (Engineering-Science, Inc., 1992) from the HVW and from the VMPs closest to and furthest from the HVW. Additionally, these soil gas samples will be used to predict potential air emissions, to determine the reduction in BTEX and total volatile hydrocarbons (TVH) during the 1-year test, and to detect any migration of these vapors form the source area. from

Soil gas sample canisters will be placed in a small cooler and packed with foam pellets to prevent excessive movement during shipment. Samples will not be sent on ice to prevent condensation of hydrocarbons. A chain-of-custody form will be filled out, and the cooler will be shipped to the Air Toxics laboratory in Rancho Cordova, California for analysis.

3.4 Air Monitoring

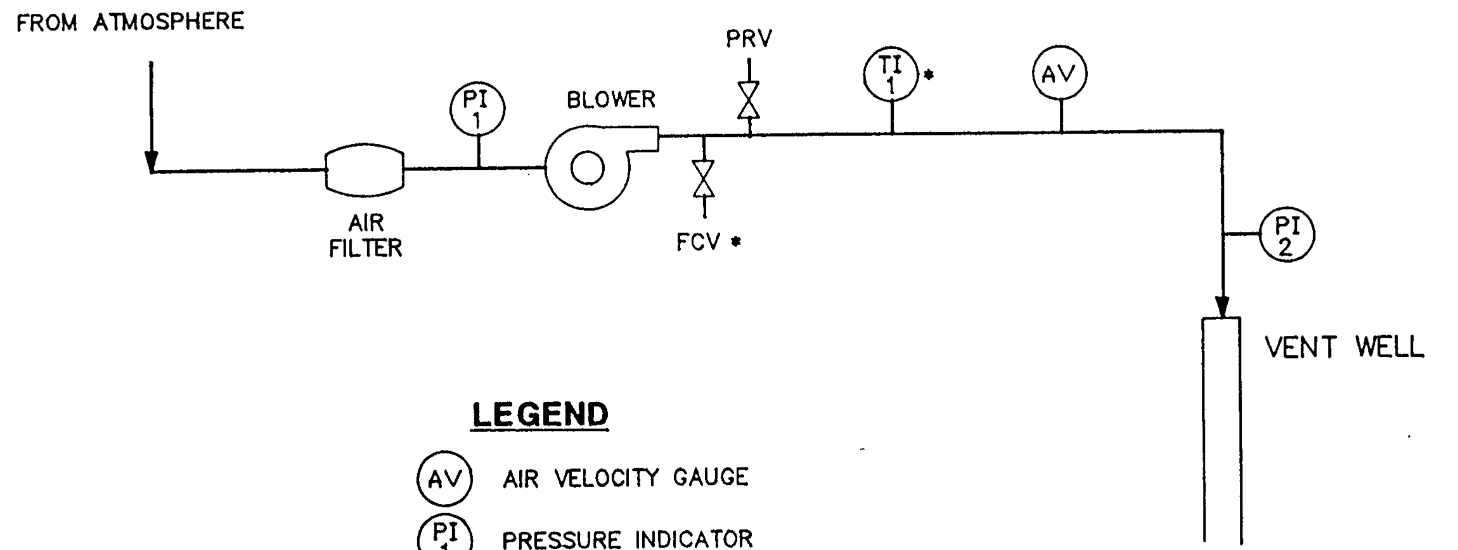
The bioventing technique will minimize the loss of volatiles to the atmosphere by reducing air injection rates to the minimum required for oxygen supply for biodegradation. During air injection, the air will be monitored for volatile hydrocarbons at the soil surface and in the breathing zone to account for any volatilization that does occur and to ensure safe working conditions.

3.5 Blower System

A 1-horsepower regenerative blower capable of injecting air at a flow rate of 20 to 40 scfm at a pressure of 2 pounds per square inch will be used to conduct the initial air permeability test at these sites. Air injection will be used to provide oxygen to soil bacteria and to minimize emissions of volatiles to the atmosphere. If initial testing indicates that less pressure is required to supply oxygen throughout the test volume, a smaller blower will be installed for extended testing. Figure 3.4 is a schematic of a typical air injection system that will be used for pilot testing at this site. The maximum power requirement anticipated for this pilot test is a 230-volt, single-phase, 30-amp service. Additional details on power supply requirements are described in Section 5.0, Base Support Requirements.

3.6 In Situ Respiration Test

The objective of the *in situ* respiration test is to determine the rate at which soil bacteria degrade petroleum hydrocarbons. Respiration tests will be performed at every VMP where bacteria biodegradation of hydrocarbons is indicated by low oxygen levels and elevated carbon dioxide concentrations in the soil gas. Air will be injected into each VMP depth interval containing low levels (<2%) of oxygen. A 20-hour air injection period will be used to oxygenate local contaminated soils. At the end of the 20-hour air injection period, the air supply will be cut off, and oxygen and carbon dioxide levels will be monitored for the following 48 to 72 hours. The decline in oxygen and increase in carbon dioxide concentrations over time will be used to estimate rates of bacterial degradation of fuel residuals. Helium will also be



LEGEND

AV	AIR VELOCITY GAUGE
PI 1	PRESSURE INDICATOR
TI 1	TEMPERATURE INDICATOR
FCV	FLOW CONTROL VALVE
PRV	PRESSURE RELIEF VALVE
*	OPTIONAL

26827-04, 10/14/92 at 09:13

FIGURE 3.4

BLOWER SYSTEM INSTRUMENTATION DIAGRAM FOR AIR INJECTION

Patrick AFB, Florida

ENGINEERING-SCIENCE, INC.

Denver, Colorado

injected at one or two points to estimate oxygen diffusion rates in site soils. This estimated rate of diffusion will be used to separate oxygen diffusion and biodegradation components of the measured rate of oxygen consumption.

3.7 Air Permeability Test

The objective of the air permeability test is to determine the extent of the subsurface that can be oxygenated using the HVW. Air will be injected into the 4-inch-diameter HVW using the blower unit, and pressure response will be measured at each VMP with differential pressure gages to determine the region influenced by the unit. Oxygen will also be monitored in the VMPs to ascertain that oxygen levels in the soil increase as the result of air injection. One air permeability test lasting 4 to 8 hours will be performed.

3.8 Installation of Extended Pilot Test Bioventing System

Extended, 1-year bioventing systems will also be installed at Site FTA-2. At the site, the base will be requested to provide a power pole with a 230-volt, single-phase, 30-amp breaker box, one 230-volt receptacle, and two 115-volt receptacles. Depending on the availability of a base electrician, a base electrician or a licensed electrician subcontracted to ES will assist in wiring the blowers to line power. The blower will be housed in a small, prefabricated shed to provide protection from the weather. The system will be in operation for 1 year, and every 6 months, ES-Denver personnel will conduct *in situ* respiration tests to monitor the long-term performance of this bioventing system. Weekly system checks will be performed by Patrick AFB personnel. If required, major maintenance of the blower unit may be performed by ES-Orlando personnel. Detailed blower system information and a maintenance schedule will be included in the operation and maintenance (O&M) manual provided to the base. More detailed information regarding the test procedures can be found in the protocol document.

4.0 EXCEPTIONS TO PROTOCOL PROCEDURES

The testing procedures that will be used to measure the air permeability of the soil and *in situ* respiration rates are described in Sections 4 and 5 of the protocol document (Hinchee et al., 1992). The only foreseen exceptions to field testing protocol procedures are the possible use of an existing well as a background VMP and the installation of an HVW. The deviation from standard vent well design is necessary to maximize the radius of oxygen influence and the ultimate success of the bioventing test. Current site conditions do not support the use of a vertical vent well, as this type of well construction would most likely result in injected air short-circuiting to the surface. Installation of a HVW will require excavation with a backhoe equipped with a narrow (12-inch) bucket.

Soil borings for vapor monitoring point installations will be advanced using a hand auger at this site. A drilling contractor will not be needed for this site, and the typical borehole diameter for each monitoring point will be approximately 4 inches, as illustrated in Figure 3.4.

5.0 BASE SUPPORT REQUIREMENTS

5.1 Test Preparation

The following base support is needed prior to the arrival of an excavation contractor and the ES test team:

- Confirmation of regulatory approval for the pilot test.
- Assistance in obtaining a digging permit at the FTA-2 site.
- A breaker box mounted to a new power pole on the site which can supply 230-volt, single-phase, 30-amp service for the initial and extended pilot tests. The breaker box should be located 5 feet above the ground and should include one 230-volt outlet and two 110-volt outlets to support pilot testing equipment.
- Provide any paperwork required to obtain gate passes and security badges for approximately four ES employees and two excavation contractors. Vehicle passes will be needed for three trucks.

During the initial 3-week pilot test, the following base support is needed:

- Twelve square feet of desk space and a telephone in a building located as close to the site as practical.
- A decontamination pad where the excavation contractor can clean the backhoe bucket.
- Acceptance of responsibility by Patrick AFB for soil cuttings from HVW trench excavation and VMP borings, including any drum sampling to determine hazardous waste status.
- The use of a fax machine for transmitting 15 to 20 pages of test results.

During the 1-year extended pilot test at Site FTA-2, the following support is needed:

- Check the blower system at the site once a week to ensure that it is operating and to record the air injection pressure. ES will provide a brief training session and an O&M checklist for this procedure.
- Notify Mr. Steve Archabal, ES-Orlando (407) 841-8114; Mr. Doug Downey, ES-Denver, (303) 831-8100; or Mr. Jim Williams, AFCEE, (800) 821-4528, ext. 246, if the blower or motor stop operating.
- Arrange site access for an ES technician to conduct *in situ* respiration tests approximately 6 months and 1 year after the initial pilot test.

5.2 Regulatory Interface

Base personnel are responsible for obtaining permission to conduct pilot tests from the Florida Department of Environmental Regulation (FDER). Unless directed by AFCEE or the base point of contact, no direct contact will be made between ES and the regulatory agencies.

6.0 PROJECT SCHEDULE

The following schedule is contingent upon timely approval of this pilot test work plan:

Event	Date
Draft Test Work Plan to AFCEE/Patrick AFB	October 19, 1992
Notice To Proceed	November 19, 1992
Begin Pilot Test	January 1993
Complete Initial Pilot Test	February 1993
Interim Results Report	March 1993
Second Respiration Test	September 1993
Final Respiration Test	March 1994
Final Results Report	

After a period of 1 year, a decision will be made by AFCEE and the base to either remove the pilot system or to expand the system for full-scale remediation of the site soils.

7.0 POINTS OF CONTACT

Ed Worth
45 CES/DEEV
Patrick AFB, FL 32925
(404) 494-7288

Major Ross Miller/Mr. Jim Williams
AFCEE/ESR
Brooks AFB, Texas 78235-5000
(800) 821-4528 Ext 282/246

Doug Downey
Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado 80290
(303) 831-8100

8.0 REFERENCES

O'Brien & Gere Engineers, Inc. 1990. *Installation Restoration Program Phase II, Remedial Investigation/Feasibility Report Study, Stage 2, Patrick Air Force Base.* Tampa, Florida. December.

Engineering-Science, Inc. 1992. *Project Management Plan for AFCEE Bioventing,* Appendix D, Field Sampling Plan. Denver, Colorado. April.

Hinchee, R.E., Ong, S.K., Miller, R.N., Downey, D.C., Frandt, R., 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* Columbus, Ohio. January.

PART IB

Draft Test Work Plan

For Site FTA-2
Cape Canaveral AFS, Florida
and
BX Service Station
Patrick AFB, Florida

TABLE OF CONTENTS

FIGURES

TABLES

DRAFT

**BIOVENTING TEST WORK PLAN FOR
FIREFIGHTING TRAINING AREA 2 (FTA-2)
CAPE CANAVERAL AFS, FLORIDA
AND
BX SERVICE STATION (PPOL-2)
PATRICK AFB, FLORIDA**

Not reflected in wp

1.0 INTRODUCTION

This site-specific work plan presents the scope of multi-phase bioventing pilot tests for *in-situ* treatment of fuel-contaminated soils at the Firefighting Training Area designated as Site FTA-2 at Cape Canaveral Air Force Station (AFS), Florida, and the BX Service Station, designated as PPOL-2 at Patrick Air Force Base (AFB), Florida. The proposed pilot tests will be performed by Engineering-Science, Inc. (ES). The three primary objectives of the proposed pilot tests are: 1) to assess the potential for supplying oxygen throughout the contaminated soil depth, 2) to determine the rate at which indigenous microorganisms will degrade the fuel when stimulated by oxygen-rich soil gas, and 3) to evaluate the potential for sustaining these rates of biodegradation until fuel contamination is remediated to concentrations below regulatory standards.

If bioventing proves to be a feasible technology for these sites, pilot test data may be used to design a full-scale remediation system and to estimate the time required for remediating soils to regulatory standards. An added benefit expected from the pilot testing at these areas is that a significant amount of the fuel contamination should be biodegraded during the 1-year pilot test, as the testing will take place within the most contaminated soils that have been detected at the site.

The pilot tests will utilize one horizontal air injection vent well (HVW) at the BX Service Station and three vertical air injection vent wells (VWs) at FTA-2. Each site will be equipped with a blower capable of sustaining a flow rate of 20 to 40 standard cubic feet per minute (scfm). Vertical air injection VW tests typically produce an effective radius of influence of approximately 20 to 40 feet. As is expected at the BX Service Station, HVWs placed in areas with a shallow water table may have reduced effective radii of influence. The design air injection rate and actual radius of influence for the sites will depend on soil properties and other factors. Rates of *in situ* fuel biodegradation will be determined for individual soil vapor monitoring points (VMPs) that will be installed around the HVW and VWs.

Additional background information on the development and recent success of the bioventing technology is found in the protocol document entitled *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Hinchee et al. 1992). This protocol document is a supplement to the site-specific work plan and it will also serve as the primary reference for pilot test VW, HVW, and VMP designs and

detailed test objectives and procedures. Unless otherwise noted, test procedures outlined in the protocol document will be used during the pilot test at Site FTA-2 and the BX Service Station.

2.0 SITE DESCRIPTION

2.1 Location and History

2.1.1 Location and History for Site FTA-2

Site FTA-2 is located north of Titan III Road approximately 400-500 feet north of the Banana River on CCAFS (Figure 2.1). Site FTA-2 consists of an unlined, earth-bermed circular burn pit approximately 100 feet in diameter. The bermed area was used from 1965 to 1985 for firefighting training exercises. A variety of combustible wastes (e.g. contaminated fuels and waste oils) were burned at the site, while no containment system was used to prevent direct infiltration of fuel into the soils.

A study conducted in 1988 indicated that total recoverable petroleum hydrocarbons (TRPH) were detected at a maximum concentration of 43,100 milligrams per kilogram (mg/kg) in the soil samples collected at the site (O'Brien & Gere, 1990). The significant hydrocarbon soil contamination found at this site is the primary target for bioventing treatment.

A soil gas survey was conducted by ES at site FTA-2 on January 5, 1993. A 20-foot by 20-foot grid was laid out in the field where previous sampling had determined significant hydrocarbon soil contamination. Oxygen (O_2), carbon dioxide (CO_2), and total volatile petroleum hydrocarbon (TVPH) measurements were collected at depths of 2.5 and 5.0 feet below ground surface (bgs), at nine grid locations within the former burn pit area. Based on the results of the survey, significant soil contamination still exists within the 40-foot by 40-foot area surveyed. Figure 2.2 presents the soil gas survey point locations. Table 2.1 presents the results of the soil gas survey.

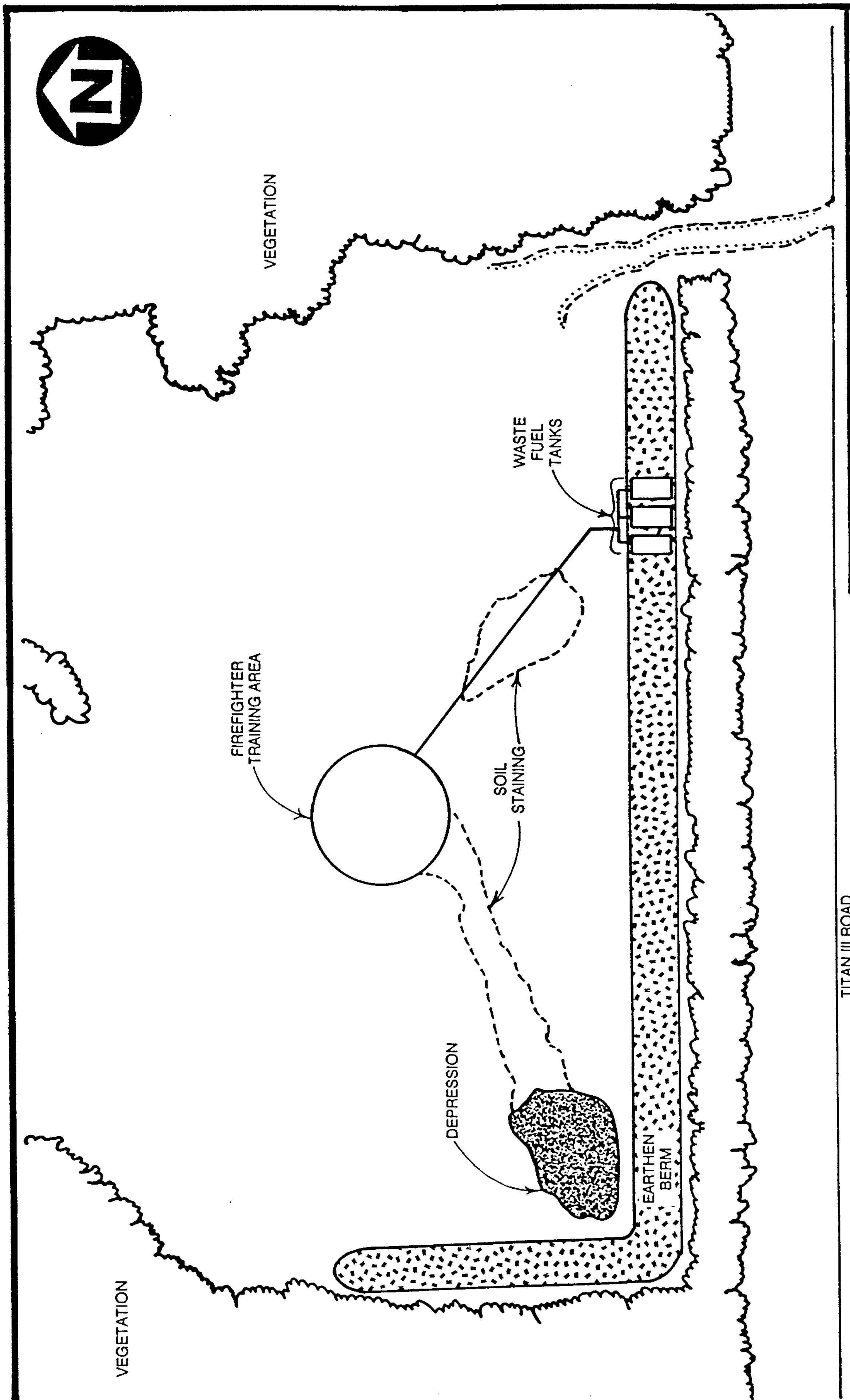
2.1.2 Location and History for the BX Service Station

The BX Service Station (Figure 2.3) has been in service since 1954. In 1973, four 3,000-gallon mogas underground storage tanks (USTs) were abandoned and filled with sand. The tanks were replaced with five 10,000-gallon fiberglass USTs, one of which was removed because of leaks in 1986. Contaminated soil was also removed with the UST. Leaking fuel lines found in 1985 are estimated to have lost approximately 700-gallons of mogas (O'Brien & Gere, 1990).

A Phase II assessment conducted in 1990 indicated that TRPH were detected at a maximum concentration of 386 mg/kg in soil samples collected at the site (O'Brien & Gere, 1990). The presence of hydrocarbon soil contamination, like that found at this site, is the primary target for bioventing treatment.

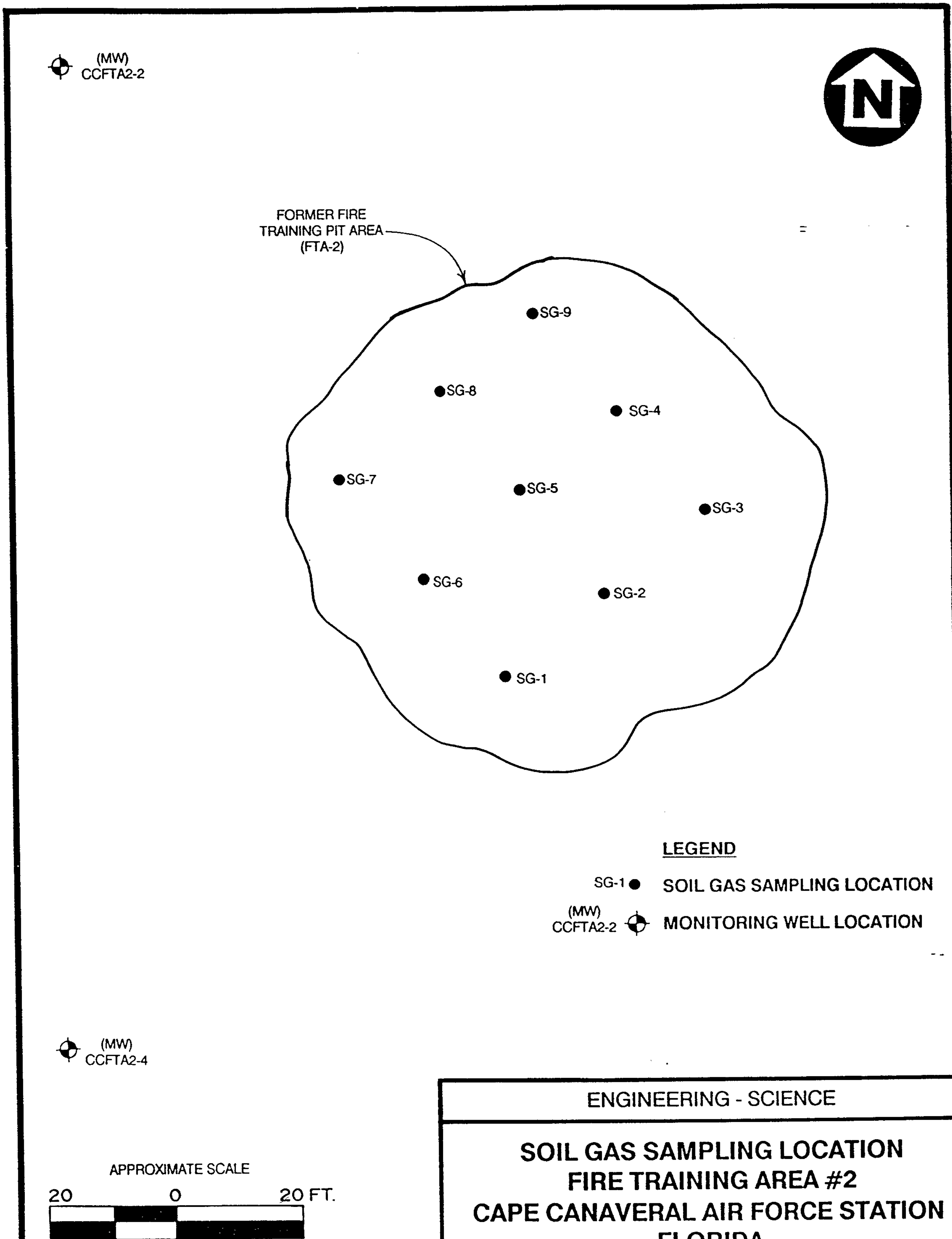
A soil gas survey was conducted by ES at the BX Service Station on January 12, 1993. A 20-foot by 20-foot grid was laid out in the field in the area where previous sampling had determined hydrocarbon soil contamination. Oxygen (O_2), carbon

FIGURE 2.1



ENGINEERING - SCIENCE

SITE PLAN
FIRE TRAINING AREA #2
CAPE CANAVERAL AIR FORCE STATION
FLORIDA



ENGINEERING - SCIENCE

SOIL GAS SAMPLING LOCATION
FIRE TRAINING AREA #2
CAPE CANAVERAL AIR FORCE STATION
FLORIDA

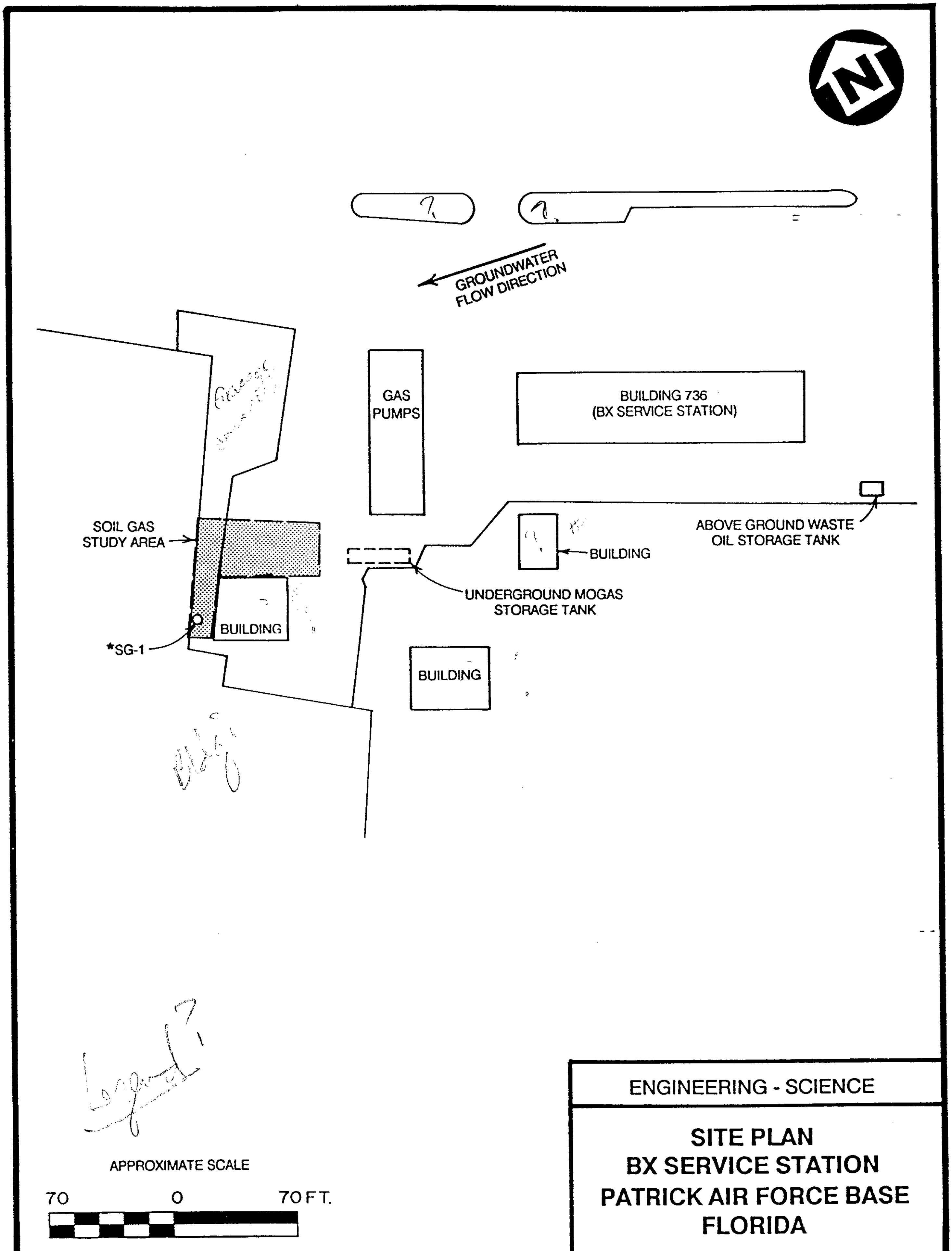
TABLE 2.1
SOIL GAS SURVEY RESULTS
FIREFIGHTER TRAINING AREA 2 (FTA-2)
CAPE CANAVERAL AIR FORCE STATION, FLORIDA

Date	Soil Gas Test Point	Depth (feet bgs)[a]	O_2 (percent)	CO_2 (percent)	TVPH Concentration (ppmv)[b]	Remarks
5 January 1993	SG-1	2.5	0.0	11.0	>10,000	Water table ~ 6.0 ft bgs
		5.0	1.5	11.5	6,400	
	SG-2	2.5	0.0	11.5	>10,000	
		5.0	0.0	12.5	>10,000	
	SG-3	2.5	0.0	11.5	>10,000	
		5.0	0.0	12.0	>10,000	
	SG-4	2.5	0.5	12.0	>10,000	
		5.0	0.5	12.0	>10,000	
	SG-5	2.5	0.0	11.0	>10,000	
		5.0	0.0	13.0	>10,000	
	SG-6	2.5	0.0	11.0	>10,000	
		5.0	0.0	13.0	>10,000	
	SG-7	2.5	0.0	11.5	>10,000	
		5.0	0.0	14.0	>10,000	
	SG-8	2.5	0.0	11.0	>10,000	
		5.0	0.0	14.0	>10,000	
	SG-9	2.5	0.0	11.5	>10,000	
		5.0	0.0	12.5	>10,000	

a/ Below ground surface (bgs)

b/ TVPH = Total volatile petroleum hydrocarbons; ppmv = parts per million, volume per volume

FIGURE 2.3



ENGINEERING - SCIENCE

SITE PLAN
BX SERVICE STATION
PATRICK AIR FORCE BASE
FLORIDA

dioxide (CO_2), and TVPH measurements were collected at depths of 1.5 and 3.0 feet bgs at 14 grid locations across the site. Based on the results of the survey, significant soil contamination still exists on-site. Figure 2.4 presents the soil gas survey point locations. Table 2.2 presents the results of the soil gas survey.

2.2 Site Geology

2.2.1 Geology for Site FTA-2

Because the bioventing technology is applied to the unsaturated soils, this section will primarily address soils above the shallow aquifer. soils at this site and to a depth of 40 feet bgs consist of predominantly unconsolidated, moderately well-sorted, fine-to-course-grained quartz sand with few to many shell fragments. Groundwater is encountered at fluctuating depths of approximately 4 to 12 feet across the site. In the area of the burn pit groundwater may fluctuate between 7 and 10 feet bgs. The generally homogeneous, sandy material at this site appears to be well suited to bioventing treatment.

2.2.2 Geology for the BX Service Station

Because the bioventing technology is applied to the unsaturated soils, this section will primarily address soils above the shallow aquifer. Soils at this site and to a depth of 25 feet bgs consist of predominantly unconsolidated, poorly to moderately well-sorted, fine-to-course-grained quartz sand with up to 40 percent shells and shell fragments. Groundwater is encountered at fluctuating depths of approximately 4 to 5 feet. The generally homogeneous, sandy material at this site appears to be well suited to bioventing treatment.

2.3 Site Contaminants

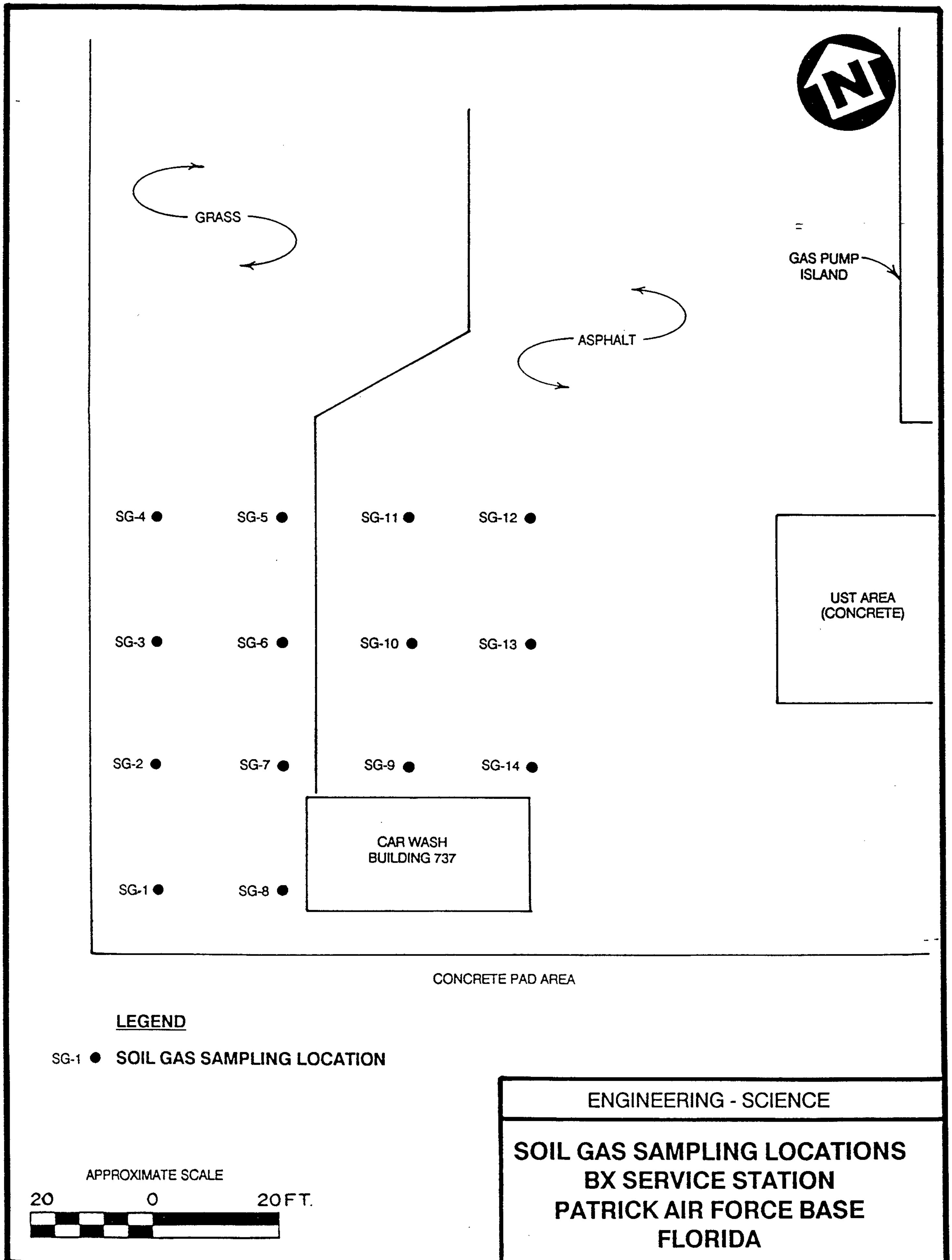
2.3.1 Contaminants for Site FTA-2

The primary contaminants at Site FTA-2 are petroleum hydrocarbons, which have been detected in the soils above the shallow aquifer. A maximum TRPH concentration of 43,100 mg/kg has been detected in the surface soils sampled at a depth between 2 and 4 feet bgs. Samples from the 1988 soil borings collected inside the burn pit area and above the shallow aquifer showed TRPH concentrations from 4,750 mg/kg to 43,100 mg/kg. Volatile organic compounds benzene, toluene, ethylbenzene, and total xylenes (BTEX) were detected in both soil and groundwater at the site. Traces of several chlorinated solvents have also been detected in soil and groundwater (O'Brien & Gere, 1990).

2.3.2 Contaminants for the BX Service Station

The primary contaminants at the BX Service Station are petroleum hydrocarbons, which have been detected in the soils above the shallow aquifer. A maximum TRPH concentration of 386 mg/kg has been detected in the surface soils sampled. Samples from the 1990 soil borings collected in the vicinity of the tank farm and in the unsaturated soils showed TRPH concentrations from 37.3 mg/kg to 386 mg/kg. Volatile organic compounds toluene, ethylbenzene, and xylenes were also detected in both soil and groundwater at the site (O'Brien & Gere, 1990).

FIGURE 2.4



GRASS
ASPHALT
GAS PUMP ISLAND
UST AREA (CONCRETE)
SG-4
SG-5
SG-11
SG-12
SG-3
SG-6
SG-10
SG-13
SG-2
SG-7
SG-9
SG-14
SG-1
SG-8
CAR WASH BUILDING 737
CONCRETE PAD AREA
LEGEND
SG-1 SOIL GAS SAMPLING LOCATION
APPROXIMATE SCALE
20 0 20 FT.
ENGINEERING - SCIENCE
SOIL GAS SAMPLING LOCATIONS
BX SERVICE STATION
PATRICK AIR FORCE BASE
FLORIDA

TABLE 2.2
SOIL GAS SURVEY RESULTS
BX SERVICE STATION (PPOL-2)
PATRICK AIR FORCE BASE, FLORIDA

Date	Soil Gas Test Point	Depth (feet bgs)[a]	O_2 (percent)	CO_2 (percent)	TVPH Concentration (ppmv)[b]	Remarks
12 January 1993	SG-1	1.5	20.5	0.8	30	Water table ~ 3.5 ft bgs
		3.0	20.5	0.8	32	
	SG-2	1.5	20.0	0.9	35	
		3.0	20.0	1.0	45	
	SG-3	1.5	20.0	0.8	38	
		3.0	20.0	0.8	50	
	SG-4	1.5	20.5	0.5	42	
		3.0	20.5	0.8	45	
	SG-5	1.5	17.0	3.0	72	
		3.0	16.5	3.2	82	
	SG-6	1.5	14.5	2.5	75	
		3.0	9.5	4.5	90	
	SG-7	1.5	4.0	10.0	96	
		3.0	0.0	12.5	3,500	
	SG-8	1.5	0.0	13.0	9,000	
		3.0	0.0	13.0	> 10,000	
	SG-9	1.5	0.0	12.0	> 10,000	
		3.0	0.0	12.0	> 10,000	
	SG-10	1.5	0.0	12.0	> 10,000	
		3.0	0.0	12.0	> 10,000	
	SG-11	1.5	6.0	9.5	70	
		3.0	4.0	10.5	90	
	SG-12	1.5	0.0	13.0	4,000	
		3.0	0.0	13.0	4,400	
	SG-13	1.5	0.0	12.0	> 10,000	"
		3.0	0.0	12.0	> 10,000	
	SG-14	1.5	0.0	11.0	6,500	
		3.0	0.0	11.0	> 10,000	

a/ Below ground surface (bgs)
b/ TVPH = Total volatile petroleum hydrocarbons; ppmv = parts per million, volume per volume

3.0 PILOT TEST ACTIVITIES

3.1 Introduction

The purpose of this section is to describe the proposed location of three VWs and three VMPs at site FTA-2, and the proposed location of one HVW and four VMPs at the BX Service Station. Soil sampling procedures and the blower configuration that will be used to inject air (oxygen) into the contaminated soils are also discussed in this section. Pilot test activities will be confined to the unsaturated soils. No dewatering will take place during the pilot tests. Existing monitoring wells located in uncontaminated soils which have a portion of their screened interval above the water table may be used as a background monitoring point (MP) to measure the composition of background soil gas.

3.2 Well Siting and Construction

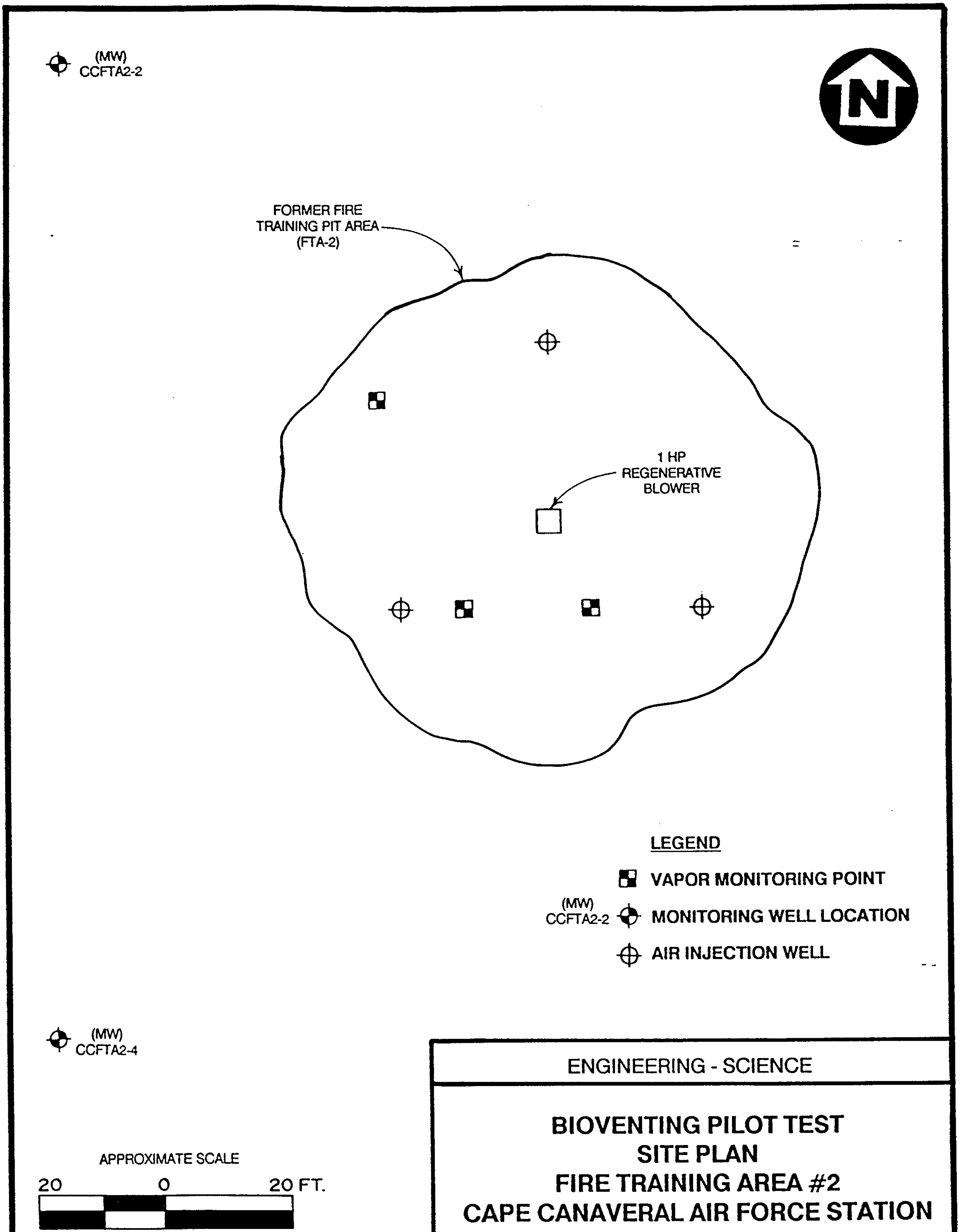
3.2.1 Well Siting and Construction for Site FTA-2

A general description of criteria for siting the three VWs and associated VMPs are included in the protocol document. Figure 3.1 illustrates the proposed location of the VWs and VMPs at site FTA-2. These locations were selected based on available analytical data and the soil gas survey conducted on 5 January 1993.

The analytical data shows elevated hydrocarbon contamination extending from ground surface to the groundwater table throughout the burn pit area. This area is expected to have a high average TPH concentration, in the several thousand range. The soil gas survey conducted in this area showed the soils to be oxygen depleted ($<2\%$), contain high TVPH concentrations ($>10,000$ ppmv) and elevated CO_2 ($>11\%$). Increased biological activity should be stimulated by oxygen-rich soil gas ventilation during pilot test operations. Final location of the VWs may vary slightly from the proposed locations if significant soil contamination is not observed during the well installation boring.

Due to the relatively shallow depth of unsaturated soil contamination at this site (<8 feet bgs) and the potential for moderately permeable soil conditions, the radius of venting influence around the VWs is expected to approach 40 feet. A total of three VMPs will be located within a 20-foot and 30-foot radius of the VWs. A soil gas probe or background well will be installed in uncontaminated soils, or an existing uncontaminated monitoring well with a screened interval above the water table will be used to measure background levels of oxygen and carbon dioxide. Additionally, the well will be used to determine if natural carbon sources are contributing to oxygen uptake during the *in situ* respiration test. Additional details on the *in situ* respiration test are found in Section 5.7 of the protocol document.

The VW will be constructed of 4-inch inside diameter Schedule 40 PVC, with a five foot interval of 0.04 slotted screen set between 3 and 8 feet bgs (the deepest seasonal groundwater elevation expected). Flush-threaded PVC casing and screen will be used with no organic solvents or glues. The filter pack will be clean, well-rounded course silica sand (99% retained on a 0.040 slotted screen) and will be placed in the annular space of the screened interval. A 2-foot layer of bentonite will be placed directly over the filter pack. The first foot of bentonite will consist of



ENGINEERING - SCIENCE

BIOVENTING PILOT TEST
SITE PLAN
FIRE TRAINING AREA #2
CAPE CANAVERAL AIR FORCE STATION
FLORIDA

bentonite pellets hydrated in place with potable water. This layer of pellets will prevent the addition of the bentonite slurry from saturating the filter pack. The remaining one foot of bentonite will be fully hydrated and mixed above ground and the slurry tremied into the annular space to produce an air tight seal above the screened interval. Then, a one foot layer of cement/bentonite grout will be placed on top of the bentonite slurry to complete the seal to ground surface. A complete seal is critical to prevent injected air from short-circuiting to the surface during the bioventing test. Figure 3.2 illustrates the proposed VW construction details for this site.

A typical multi-depth vapor monitoring point (VMP) installation for this site is shown in Figure 3.3. Because of the rather shallow depth to groundwater, only two air monitoring points will be required for each location. Soil gas oxygen and carbon dioxide concentrations will be monitored at depth intervals of approximately 3-feet and 6-feet at each location. Multi-depth monitoring will confirm that the entire soil profile is receiving oxygen and be used to measure fuel biodegradation rates at both depths. The annular space between these two monitoring points will be sealed with bentonite to isolate the monitoring intervals. As with the VWs, several inches of bentonite pellets will be used to shield the filter pack from rapid infiltration of bentonite slurry additions. Additional details on VW and monitoring point construction are found in Section 4 of the protocol document.

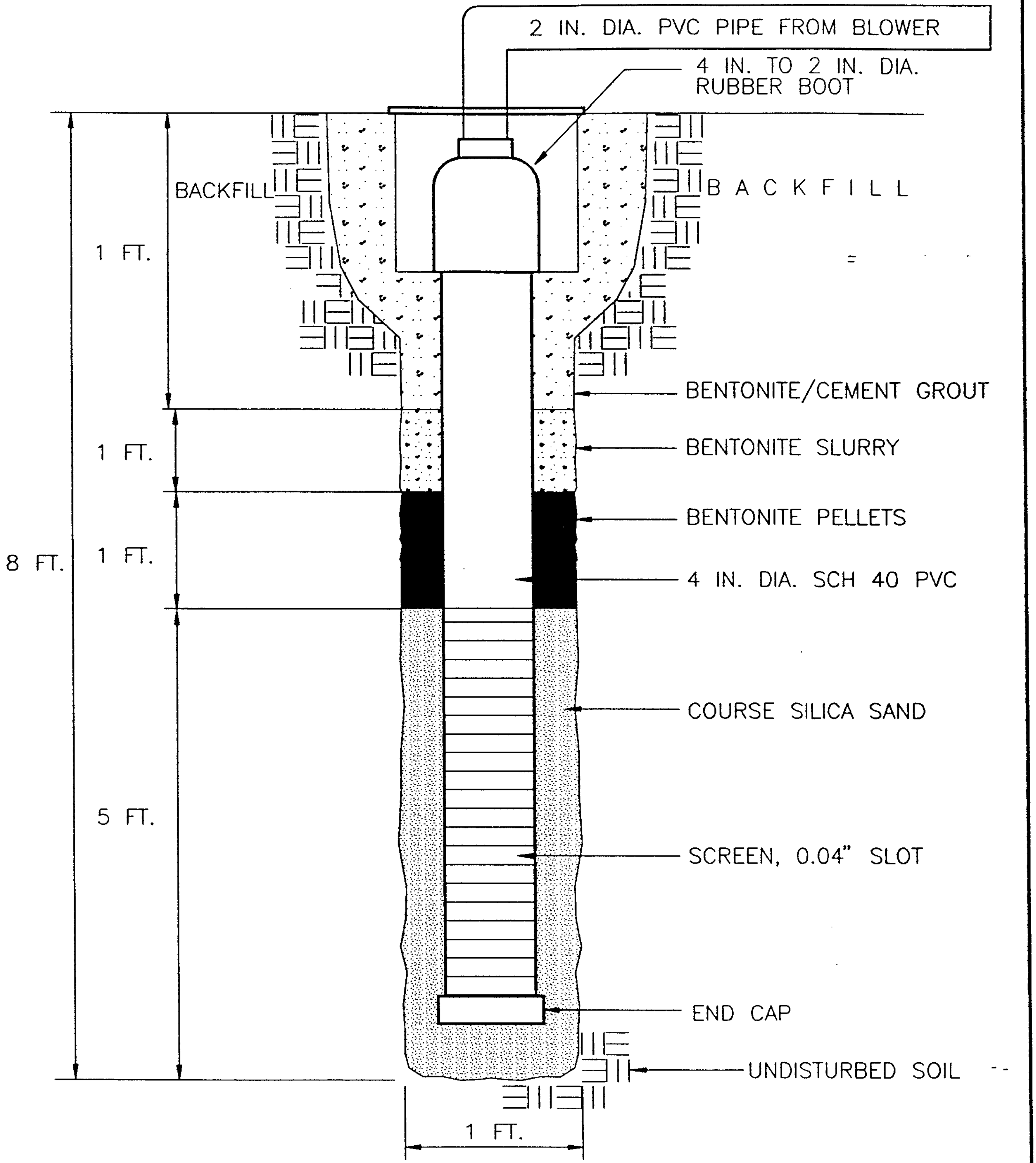
Following installation of the vent wells and vapor monitoring points, the entire area inside FTA-2 may be covered with 20-mil polyethylene sheeting to provide an additional barrier to prevent short-circuiting of the injected air. In order to insure that the poly sheeting seals to the ground surface, a six inch layer of fill material may be placed on top of the sheeting. The installation of the sheeting and cover fill may be conducted if, based on field observations, is appears that air is short-circuiting to the surface.

3.2.2 Well Siting and Construction for the BX Service Station

A general description of criteria for siting a central HVW and VMPs are included in the protocol document. Figure 3.4 illustrates the proposed location of the HVW and VMPs at site BX Service Station. These locations were selected based on available analytical data and the soil gas survey conducted on 12 January 1993.

The HVW will be installed in a narrow trench excavated in contaminated soils just above the water table. Orientation of the trench axis is expected to be approximately east-west, in the most contaminated soil interval at the site. Four VMPs will be placed at varying distances from the trench. The final locations of the VMPs may vary slightly from the locations shown in Figure 3.4 if significant fuel contamination is not observed in the boring for the first VMP.

Based on site investigation data, the central HVW should be located in close proximity to soil gas survey points SG-10 and SG-13. This area is expected to have elevated TRPH values based on the data collected during the survey. The soil gas survey in this area showed the soils to be oxygen depleted ($<2\%$), contain high TVPH concentrations ($>10,000$ ppmv), and elevated CO_2 ($>12\%$). Increased



NOT TO SCALE

FIGURE 3.2
INJECTION VENTING WELL CONSTRUCTION DETAIL
SITE FTA – 2
CAPE CANAVERAL

ENGINEERING–SCIENCE, INC.
Orlando, Florida

ES

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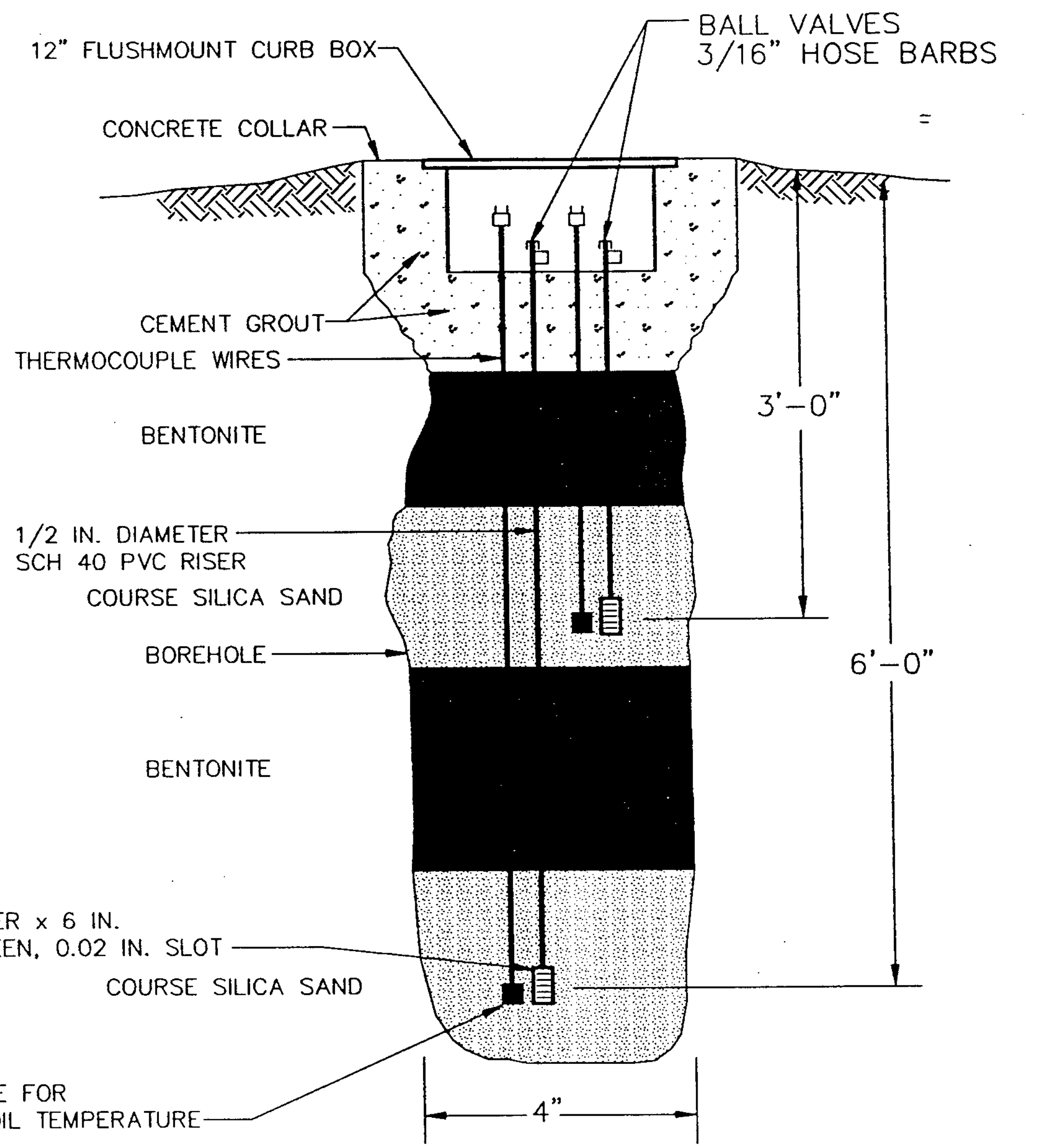

NOT TO SCALE

FIGURE 3.3
FIRE TRAINING AREA #2
MONITORING POINT
CONSTRUCTION DETAIL
CAPE CANAVERAL A.F.S.

ENGINEERING-SCIENCE, INC.
Orlando, Florida

ES

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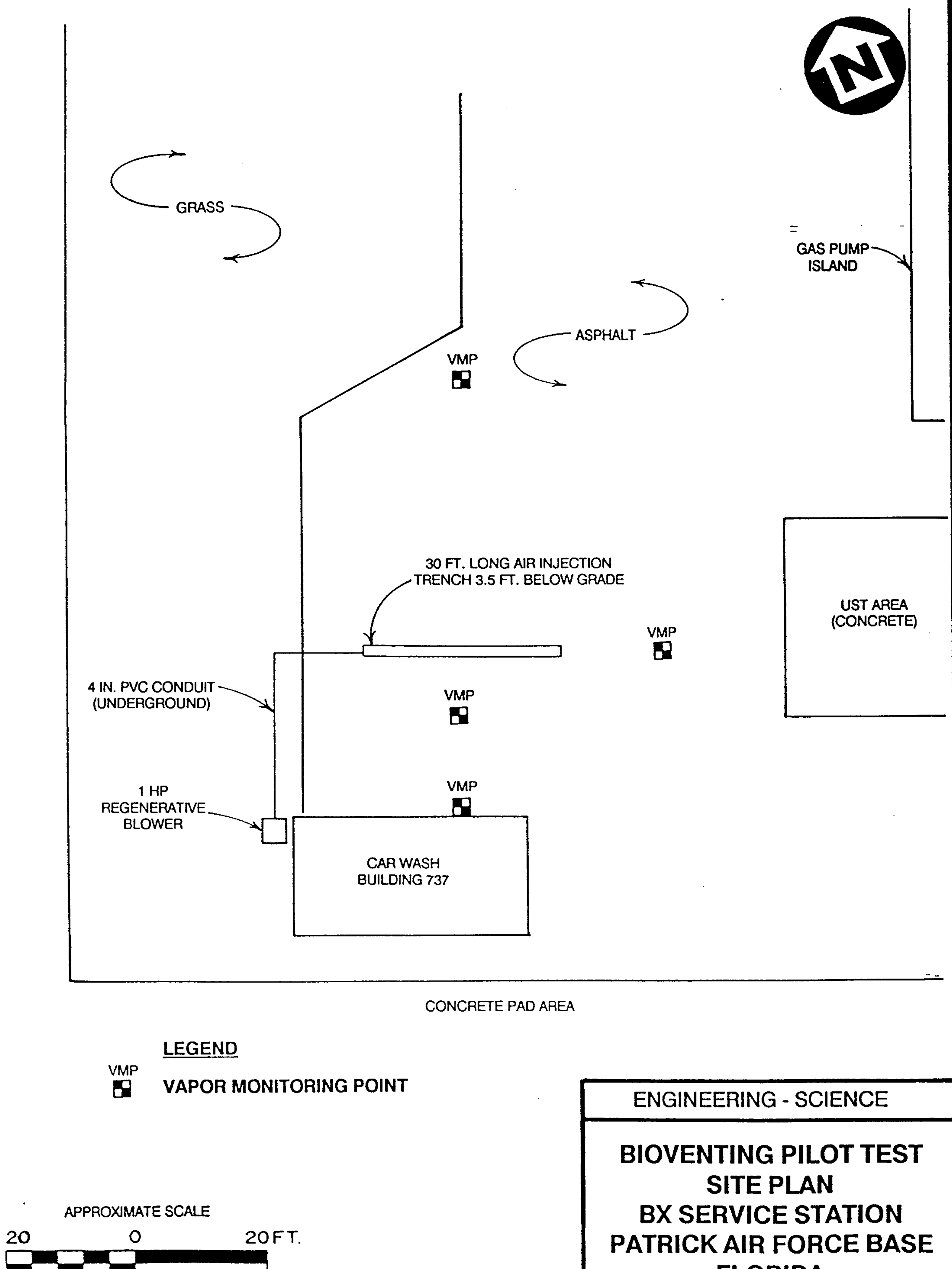


ENGINEERING - SCIENCE

BIOVENTING PILOT TEST SITE PLAN BX SERVICE STATION PATRICK AIR FORCE BASE FLORIDA

biological activity should be stimulated by oxygen-rich soil gas ventilation during pilot test operations.

Considering the shallow depth of contamination in unsaturated soils at this site (<5 feet bgs), the soil lithology, and the horizontal design configuration of the air injection well required to accommodate shallow water table conditions the radius of venting influence around the central HVW is expected not to exceed 40 feet. The installation of an HVW with a bentonite seal above the trench is expected to produce a greater area of oxygen influence than a vertical VW design.

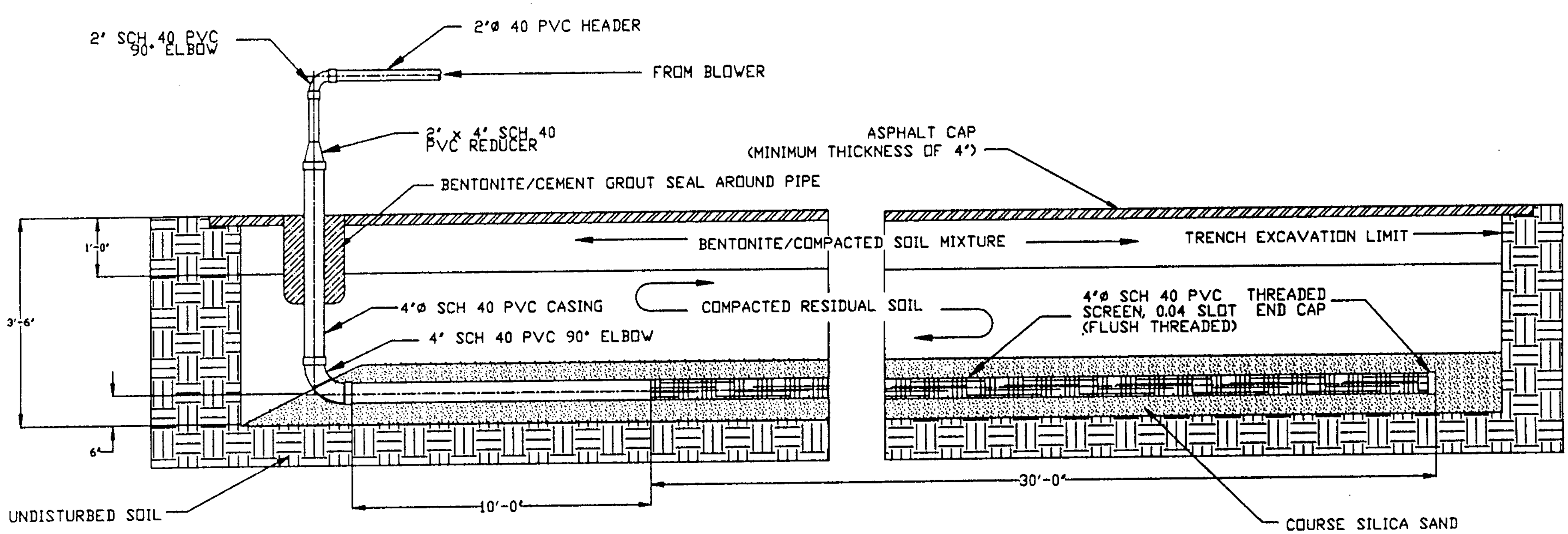
Four VMPs will be located within a 10, 15, and 40-foot radius of the central HVW (Figure 3.4). Background levels of oxygen (20.5 %) and carbon dioxide (0.8 %) were established for these soils during the soil gas survey of points SG-1 and SG-4. It is apparent from these near atmospheric concentrations of oxygen and carbon dioxide that uncontaminated soils exert little or no oxygen demand.

The central HVW will be constructed of 4-inch inside-diameter Schedule 40 polyvinyl chloride (PVC), with 30 feet of 0.04-inch slotted screen set in a narrow trench at approximately 3.5-feet bgs. This section will be followed by a 10 foot section of PVC casing connected by a PVC 90° elbow then by another 20-foot section of PVC casing then another 90° elbow and a 4-inch vertical PVC riser pipe which will be connected to the blower unit. Flush-threaded PVC casing and screen with no organic solvents or glues will be used. A filter pack of coarse silica sand will be placed entirely around the screened interval in the form of a gravel envelope. The trench will then be backfilled with the excavated residual soil and compacted to increase the soil density of this zone. The top 1 foot of the trench excavation will be completed with a 70% soil/30% bentonite mixture overlain by a four inch layer of ashpalt. The asphalt surface cap will be completed at ground surface to restore the site to its original condition. A complete surface seal is necessary in order to prevent injected air from short-circuiting to the surface during the bioventing test. Figure 3.5 illustrates the proposed HVW construction for this site.

A typical multi-depth VMP installation design will not be used for this site. A single-depth VMP installation will be used, since the water table is so shallow. Soil gas oxygen and carbon dioxide concentrations will be monitored at depth intervals of 2.5 to 3.5 feet at each location. Monitoring will confirm that the soils are receiving oxygen, and will be used to measure fuel biodegradation rates. Data from the background VMP will also be used to determine the relative natural diffusion of atmospheric oxygen into the shallow soils. Additional details on VMP construction can be found in Section 4 of the protocol document.

3.3 Handling of Soil Boring Cuttings and Excavated Soils

Cuttings from all soil borings and any remaining waste soils from trench excavation will be collected in a Department of Transportation (DOT) approved container. The containers will be labeled and then placed in a designated Patrick AFB hazardous materials storage area. These waste soils will become the responsibility of Cape Canaveral and Patrick AFB, and will be analyzed, handled, and disposed of in accordance with the current procedures for ongoing remedial



NOTES:

1. DRAWING IS NOT TO SCALE.
2. ALL FITTINGS MUST BE FLANGED OR SCREW TYPE.

FIGURE 3.5

BX SERVICE STATION PROPOSED INJECTION VENT WELL AND TRENCH CONSTRUCTION

PATRICK AFB,Florida

ENGINEERING-SCIENCE, INC.
Orlando, Florida

investigations. This project is expected to generate less than four 55-gallon drums of waste soils.

3.4 Soil and Soil Gas Sampling

3.4.1 Soil Sampling

A total of three soil samples will be collected from each of the pilot test areas during the installation of the VWs, HVW and VMPs. Sampling procedures will follow those outlined in the protocol document, with minor modifications for collection of one sample from the most contaminated interval of the VWs and HVW trench. One sample will be collected from the interval of highest apparent contamination in two of the borings for the VMPs at BX Service Station site. Soil samples will be analyzed for TRPH, BTEX, soil moisture, pH, particle sizing, alkalinity, total iron, and nutrients.

Samples will be collected by hand augering to the desired sampling depth and then driving by hand either a small-diameter Shelby tube or a split-spoon device equipped with a sampling sleeve. A photoionization detector (PID) or total hydrocarbon vapor analyzer (see protocol document Section 4.5.2) will be used to screen split-spoon samples for intervals of high fuel contamination. Additionally, the PID will be used to ensure that breathing-zone levels of volatiles do not exceed 1 part per million, per volume (ppmv) while conducting soil borings, well installations, and the trench excavation. Soil samples collected in the tubes will be immediately trimmed and aluminum foil and plastic caps will be placed over the ends. Soil samples will be labeled following the nomenclature specified in the protocol document (Section 5.5), wrapped in plastic, and placed in an ice chest maintained at a temperature of 4° Celsius for shipment. A chain-of-custody form will be filled out, and the ice chest shipped to the ES laboratory in Berkeley, California for analysis. This laboratory has been audited by the U.S. Air Force and meets all quality assurance/quality control and certification requirements for the State of California.

3.4.2 Soil Gas Sampling

A total of six initial soil gas samples will be collected in SUMMA™ cannisters in accordance with the *Bioventing Field Sampling Plan* (Engineering-Science, Inc., 1992). The samples will be collected from the HVW at the BX Service Station Site, from one of the VWs at the FTA-2 site, and one each from the VMPs closest to and furthest from the HVW (BX Service Station) and the VW (site FTA-2). These soil gas samples will be used to predict potential air emissions, to determine the reduction in BTEX and total volatile hydrocarbons (TVH) during the 1-year test, and to detect any migration of these vapors from the source area.

Soil gas sample canisters will be placed in a small cooler and packed with foam pellets to prevent excessive movement during shipment. Samples will not be sent on ice to prevent condensation of hydrocarbons. A chain-of-custody form will be filled out, and the cooler will be shipped to the Air Toxics laboratory in Rancho Cordova, California for analysis.

3.5 Air Monitoring

The bioventing technique will minimize the loss of volatiles to the atmosphere by reducing air injection rates to the minimum required for oxygen supply for biodegradation. During air injection, the air will be monitored for volatile hydrocarbons at the soil surface and in the breathing zone to account for any volatilization that does occur and to ensure safe working conditions.

3.6 Blower System

A 1-horsepower regenerative blower capable of injecting air at a flow rate of 20 to 40 scfm at a pressure of 56 inches of water will be used to conduct the initial air permeability test at these sites. Air injection will be used to provide oxygen to soil bacteria and to minimize emissions of volatiles to the atmosphere. If initial testing indicates that less pressure is required to supply oxygen throughout the test volume, the blower output will be reduced for the extended testing via an air bleed valve. Figure 3.6 is a schematic of a typical air injection system that will be used for pilot testing at this site. The maximum power requirement anticipated for this pilot test is either 230-volt, single-phase, 30-amp service or 120-volt 30 amp service. Additional details on power supply requirements are described in Section 5.0, Base Support Requirements.

3.7 In Situ Respiration Test

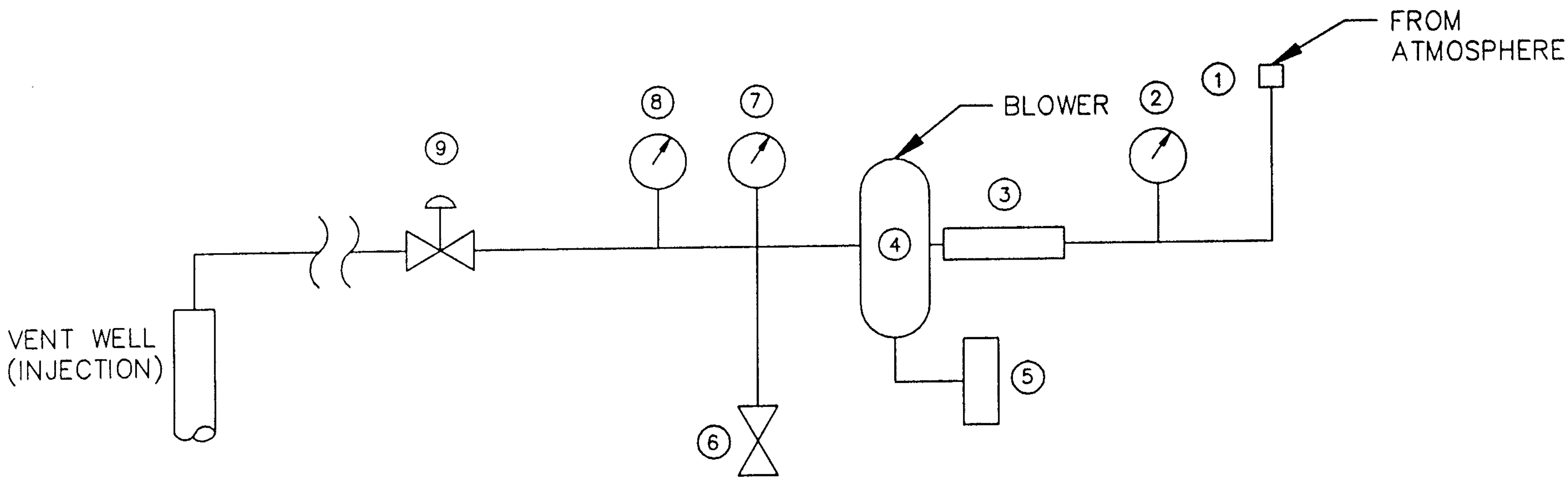
The objective of the *in situ* respiration test is to determine the rate at which soil bacteria degrade petroleum hydrocarbons. Respiration tests will be performed at the three VMPs with the highest apparent fuel contamination at each site. Air will be injected into each VMP depth interval containing low levels (<2%) of oxygen. A 20 to 24-hour air injection period will be used to oxygenate local contaminated soil. At the end of the air injection period, the air supply will be cut off, and oxygen and carbon dioxide levels will be monitored until the oxygen level falls below 5 % or for five days whichever is earlier. The decline in oxygen and increase in carbon dioxide concentrations over time will be used to estimate rates of bacterial degradation of fuel residuals. Helium will also be injected at all three points at each site to ensure that the VMPs do not leak and to estimate oxygen diffusion rates in site soils.

3.8 Air Permeability Test

The objective of the air permeability test is to determine the extent of the subsurface that can be oxygenated using the HVW or VWs. Air will be injected into the 4-inch-diameter HVW or VW using the blower unit, and pressure response will be measured at each VMP with differential pressure gauges to determine the region influenced by the unit. Oxygen will also be monitored in the VMPs to ascertain that oxygen levels in the soil increase as the result of air injection. One air permeability test lasting 4 to 8 hours will be performed.

3.9 Installation of Extended Pilot Test Bioventing System

Extended, 1-year bioventing pilot systems will also be installed at Site FTA-2 and the BX Service Station. At each site the base will be requested to provide a power pole with either 230-volt, single-phase, 30-amp breaker box or 120-volt 30



1. INLET FILTER
2. VACUUM GAUGE – INCHES OF H20
3. DRIVE MOTOR
   2.5 HP / 3450 RPM @ 60 Hz / 230 v / SINGLE PHASE / 15 A /
4. BLOWER – GAST R5125
   145 SCFM @ 3450 RPM / REGENERATIVE
5. POWER SWITCH
6. AUTOMATIC PRESSURE RELIEF VALVE – SET @ 6 psig
7. PRESSURE GAUGE (INCHES OF H20)
8. THERMOMETER (FAHRENHEIT)
9. MANUAL PRESSURE RELIEF (BLEED) VALVE – 1 1/2" BALL

FIGURE 3.6

SCHEMATIC OF BLOWER SYSTEM FOR AIR INJECTION

PATRICK AFB, FLORIDA

ENGINEERING–SCIENCE, INC.
Orlando, Florida

ES

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CREATED: 2/4/93

amp breaker box. Two 115-volt receptacles will also be required. Depending on the availability of a base electrician, a base electrician or a licensed electrician subcontracted to ES will assist in wiring the blowers to line power. The blower will be housed in a small, prefabricated shed to provide protection from the weather.

The system will be in operation for 1 year, and at 6 months and 12-months of operation, ES personnel will conduct *in situ* respiration tests to monitor the long-term performance of this bioventing system. Weekly system checks will be performed by Patrick AFB and Cape Canaveral AFS personnel. If required, major maintenance of the blower unit may be performed by ES personnel. Detailed blower system information and a maintenance schedule will be included in the operation and maintenance (O&M) manual provided to the base. More detailed information regarding the test procedures can be found in the protocol document.

4.0 EXCEPTIONS TO PROTOCOL PROCEDURES

The testing procedures that will be used to measure the air permeability of the soil and *in situ* respiration rates are described in Sections 4 and 5 of the protocol document. The only foreseen exceptions to field testing protocol procedures are the possible use of an existing well as a background VMP and installation of an HVW. The deviation from standard VW design is necessary to maximize the radius of oxygen influence and the ultimate success of the bioventing test. Site conditions at FTA-2 support the use of VWs, while at the BX Service Station, the installation of a HVW will require excavation with a backhoe equipped with a narrow (12-inch) bucket.

Soil borings for VMP installations will be advanced using a hand auger at these sites. A drilling contractor will not be needed for this procedure and the typical borehole diameter for each monitoring point will be approximately 4 inches, as illustrated in Figure 3.4.

5.0 BASE SUPPORT REQUIREMENTS

5.1 Test Preparation

The following base support is needed prior to the arrival of an excavation contractor and the ES test team:

- Confirmation of regulatory approval for the pilot test.
- Assistance in obtaining a digging permit at the FTA-2 site and the BX Service Station.
- A breaker box mounted to a new power pole on the site which can supply 230-volt, single-phase, 30-amp service for the initial and extended pilot tests. The breaker box should be located 5 feet above the ground and should include one 230-volt outlet and two 110-volt outlets to support pilot testing equipment. The proposed locations for the power poles has been provided to Mr. Hugh Houghton.

- Provide any paperwork required to obtain gate passes and security badges for approximately four (4) ES employees and two excavation contractors. Vehicle passes will be needed for three trucks.

During the initial 3-week pilot test, the following base support is needed:

- Twelve square feet of desk space and a telephone in a building located as close to the site as practical.
- A decontamination pad where the excavation contractor can clean the backhoe bucket.
- Acceptance of responsibility by Patrick AFB and Cape Canaveral AFS for soil cuttings from HVW trench excavation and VMP borings, including any drum sampling to determine hazardous waste status.
- The use of a fax machine for transmitting 15 to 20 pages of test results.

During the 1-year extended pilot test at Site FTA-2, the following support is needed:

- Check the blower system at the site once a week to ensure that it is operating and to record the air injection pressure. ES will provide a brief training session and an O&M checklist for this procedure.
- Notify Mr. Steve Archabal, ES-Orlando, (407) 841-8114; Mr. Dave Brown, ES-Syracuse, (315) 451-9560; or Capt. Chung Yen, AFCEE, (210) 536-5241, if the blower or motor stop operating.
- Arrange site access for an ES technician to conduct *in situ* respiration tests approximately 6 months and 1 year after the initial pilot test.

5.2 Regulatory Interface

Base personnel are responsible for obtaining permission to conduct pilot tests from the Florida Department of Environmental Regulation (FDER). Unless directed by AFCEE or the base point of contact, no direct contact will be made between ES and the regulatory agencies.

6.0 PROJECT SCHEDULE

The following schedule is contingent upon timely approval of this pilot test work plan:

Event	**Date**
Draft Test Work Plan to AFCEE/Patrick AFB/Cape Canaveral AFS	February 1993
Notice to Proceed	March 1, 1993
Begin Pilot Test	March 8, 1993
Complete Initial Pilot Test	April 2, 1993
Interim Results Report	May 14, 1993

Second Respiration Test	September 3, 1993
Final Respiration Test	April 1, 1994
Final Results Report	May 20, 1994

After a period of 1 year, a decision will be made by AFCEE, Patrick AFB, and Cape Canaveral AFS to either remove the pilot system or to expand the system for full-scale remediation of the site soils.

7.0 POINTS OF CONTACT

Mr. Hugh Houghton
45 CES/DEEV
Patrick AFB, FL 32925
(407) 494-4721

Major Ross Miller/Capt. Chung Yen
AFCEE/ESR/ESCT
Brooks AFB, Texas 78235-5000
(210) 536-4331/(210) 536-5241

Dave Brown
Engineering-Science, Inc.
290 Elwood Davis Road
Liverpool, New York
(315) 451-9560

Steve Archabal
Engineering-Science, Inc.
255 S. Orange Avenue, Suite 1201
Orlando, FL 32801
(407) 841-8114

8.0 REFERENCES

O'Brien & Gere Engineers, Inc. 1990. *Installation Restoration Program Phase II, Remedial Investigation/Feasibility Report Study, Stage 2, Patrick Air Force Base*. Tampa, Florida. December.

Engineering-Science, Inc. 1992. *Project Management Plan for AFCEE Bioventing*, Appendix D, Field Sampling Plan. Denver, Colorado. April

Hinchee, R.E., Ong, S.K., Miller, R.N., Downey, D.C., Frandt, R. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* Columbus, Ohio. January.

PART II

Interim Pilot Test Results Report For Three Bioventing Sites

Cape Canaveral AFS, Florida
and
Patrick AFB, Florida

Prepared for:

Air Force Center for Environmental Excellence
Brooks AFB, Texas

and

45 CES/DEEV
Patrick AFB, Florida

Prepared by:

ENGINEERING SCIENCE, INC.

255 South Orange Avenue, Suite 1201
Orlando, Florida

June 1993

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FIGURES

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APPENDICES

PART II

DRAFT INTERIM PILOT TEST RESULTS REPORT FOR FIREFIGHTER TRAINING AREA SITE FTA-2, PATRICK AFB; BX SERVICE STATION, PATRICK, AFB; AND FIREFIGHTER TRAINING AREA SITE FTA-2, CAPE CANAVERAL AFS, FLORIDA

An initial bioventing pilot test was performed at each of the following sites: 1) Firefighter Training Area Site FTA -2 at Patrick Air Force Base (AFB); 2) BX Service Station at Patrick AFB; and 3) Firefighter Training Area Site FTA-2 at Cape Canaveral Air Force Station (AFS), Florida from April 19 through 27, 1993. The purpose of this Part II report is to describe the results of the initial pilot tests and to make specific recommendations for extended testing to determine the long-term impact of bioventing to remediate the site contaminants. Descriptions of the history, geology, and site contaminants of each site are found in Part I of this report, Bioventing Pilot Test Work Plan.

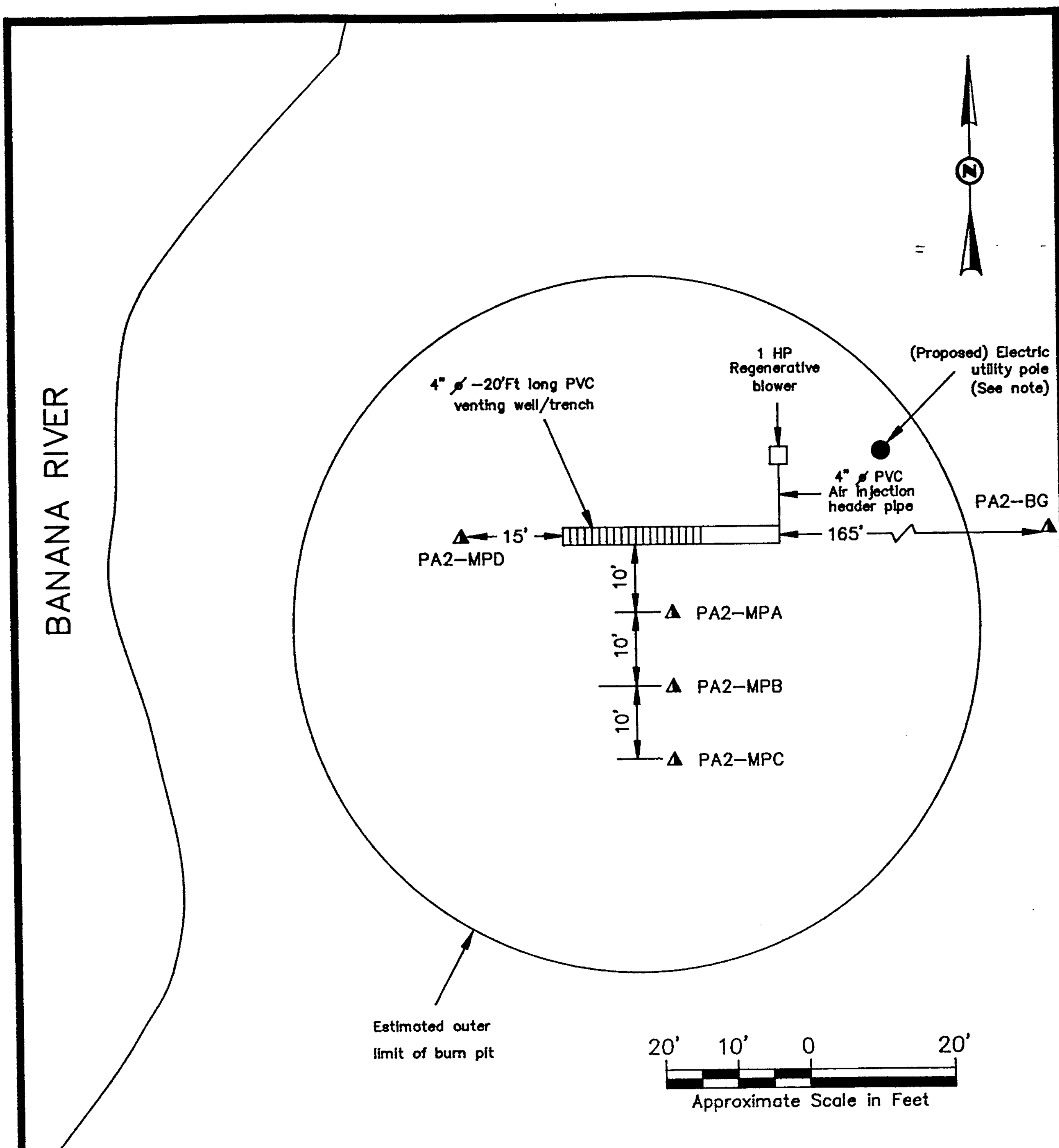
1.0 SITE FTA-2, PATRICK AFB

1.1 Pilot Test Design and Construction

The following sections describe the final design and installation of the bioventing system at site FTA-2. A horizontal trench and air injection venting well (HVW) was installed on March 11 and 12, 1993 by Engineering-Science, Inc. (ES) Orlando, Florida and a subcontractor, Groundwater Protection, Inc. (Remediation Division) of Orlando, Florida. Five permanent pressure/vapor monitoring points (MPs) were installed on March 12, 1993. The HVW construction, MP installations, and soil sampling were directed by Mr. Steve Archabal, the ES site manager. The following sections describe in more detail the final design, installation, and testing of the bioventing system at this site.

One HVW, five permanent MPs, and a blower unit in a weather-proof enclosure were installed at site FTA-2. The locations of the MPs were changed from the original work plan after a site survey indicated the potential for a larger effective radius of venting influence. A single-depth MP construction was used at the site. A monitoring depth screen interval of 3.0 to 3.5 feet below land surface (bls) was installed, due to shallow water table conditions of approximately 5.0 feet bls at this site. Figure 1.1 depicts the test area with the locations of the MPs, HVW, and

Figure 1.1



LEGEND

PA2-MPA ▲ Permanent soil vapor/pressure monitoring point.

NOTE: Interim pilot test performed prior to permanent electric hookup

AS-BUILT HORIZONTAL VENTING WELL, VAPOR MONITORING POINTS, AND BLOWER LOCATIONS
SITE FTA-2

PATRICK AFB, FLORIDA

ENGINEERING-SCIENCE, INC.
Orlando, Florida

ES

PA2-1-1.DWG

blower at site FTA-2. Figure 1.2 shows a hydrogeologic cross section in a north-south direction, perpendicular to the axis of the HVW.

1.1.1 Horizontal Air Injection Venting Well Construction

The HVW was installed within the boundaries of the former firefighter training pit area, as shown in Figure 1.1. Orientation of the HVW trench axis is in an east-west direction, and was constructed in a shallow trench excavated in visibly contaminated, oxygen-depleted soils. Soils in the immediate vicinity of the trench were darkly stained and emitted hydrocarbon odors.

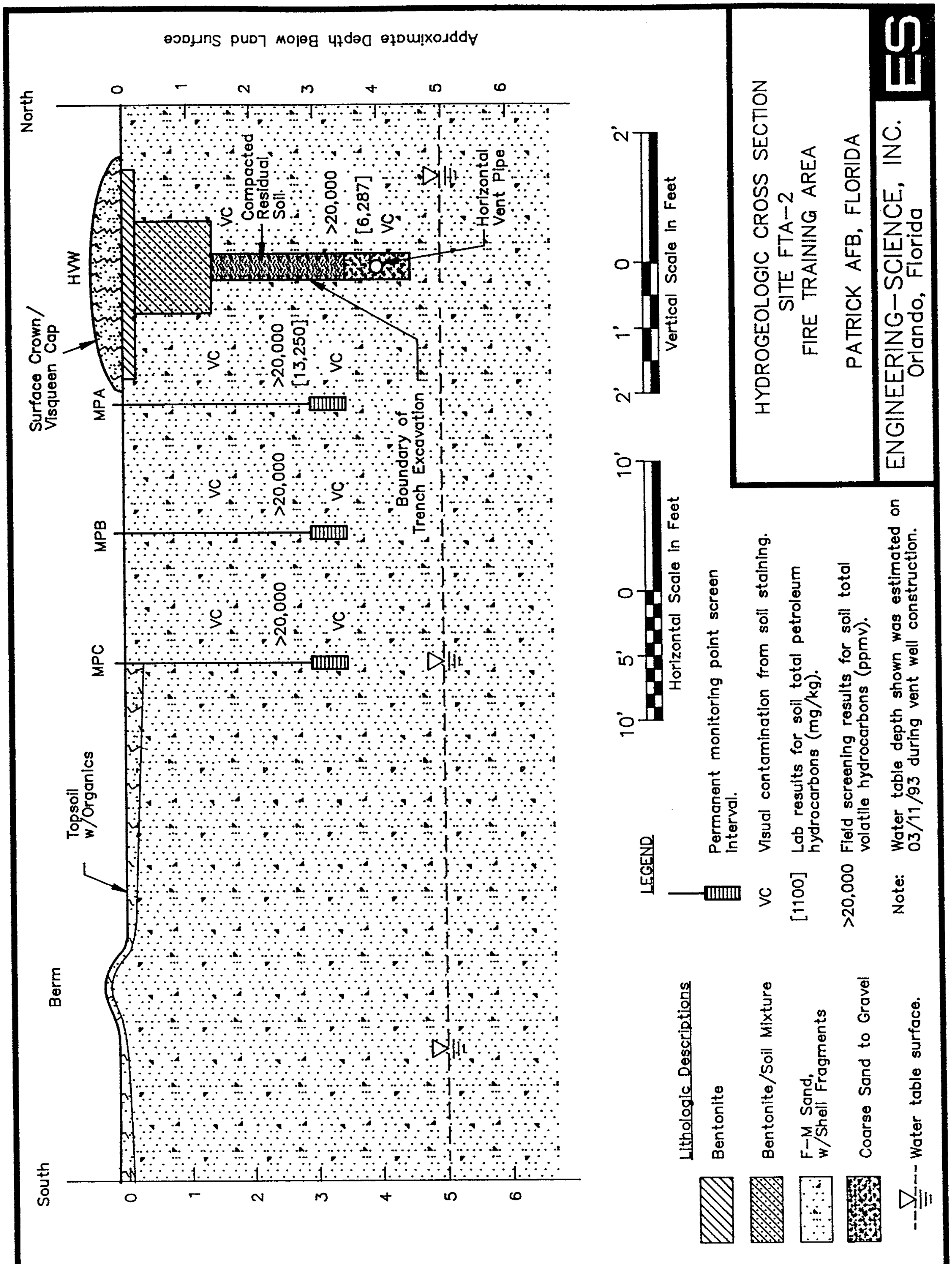
An HVW was installed at this site because of the relatively shallow water table, which prevented the proper installation of a vertical vent well (VW) according to typical AFCEE work plan protocols (Hinchee et al., 1992). Figure 1.3 shows the as-built construction details of the trench and HVW. On the date of the HVW/trench installation, water level at the FTA-2 site was approximately 5.0 feet bls. According to previous IRP reports for this site, water level elevations can vary between 4 and 6 feet bls. Consequently, the installation depth of the HVW/trench was in accordance with the proposed depth in the Bioventing Pilot Test Work Plan (see Part IA).

A backhoe equipped with a 12-inch wide bucket was used for the trench excavation. A 30x30-foot area was prepared by removing the vegetation/topsoil to a depth of approximately 3 inches bls, using the backhoe. Site preparation was completed prior to commencing with the trench excavation. The excavation was then completed to 4-feet 8-inches bls for a distance of 30 feet.

The subsurface soils encountered at this site are predominantly unconsolidated; comprised of fine to medium grained quartz sand, shells, and shell fragments with minor amounts of clayey sand. Due to the loose nature of the soil, benching was necessary along the sidewalks of the excavation to prevent the possibility of a cave-in during the installation of the HVW.

Upon completing the trench excavation, the HVW was constructed using 4-inch diameter, schedule 40 polyvinyl chloride (PVC) screen and casing. A 20-foot section of 0.03-inch slotted screen and a 10-foot section of threaded casing were installed in the excavation. The screen section was surrounded by a coarse graded (6/20) silica sand in the form of a gravel envelope. A PVC elbow equipped with a 200 pounds-per-square-inch (PSI) rubber gasket was used to connect the horizontal section of venting pipe to a vertical 4-inch diameter PVC riser pipe to the ground surface. The gravel pack was overlain by residual soil and compacted in 1-foot lifts with a tamp to help minimize vertical air losses/short-circuiting to the surface. A 1-foot layer of

Figure 1.2



PA2–1–2.DWG

residual soil and bentonite mixture was placed on top of the compacted soil in three 4-inch lifts and hydrated thoroughly between lifts. A bentonite cap 1 inch thick was placed over the trench, at ground surface, and extended 5 feet beyond the limits of the trench in all directions over the screened interval. Approximate dimensions of the bentonite cap are 14x30 feet. A surface cap of clean fill material was placed in a crown over the bentonite cap layer to help direct surface drainage away from the trench. Additionally, a 30x30-foot, 10-mil thick, plastic sheeting layer was placed over the surface soil crown, and 2 to 3 inches of soil was placed over the plastic sheeting and sloped to the edges to finish the surface cap. Figures 1.2 and 1.3 depict the various layers and surface cap discussed in trench construction.

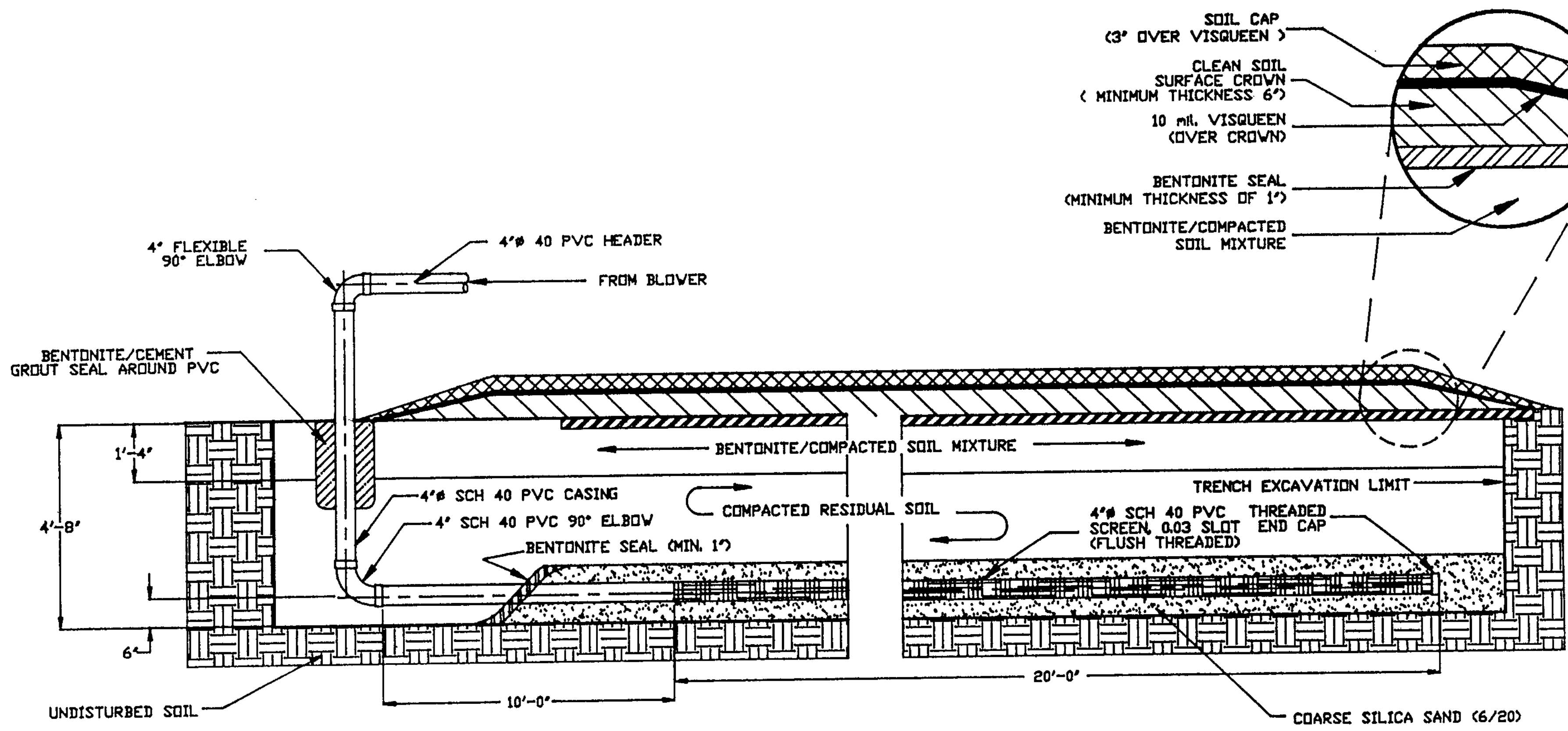
1.1.2 Permanent Monitoring Points

Five permanent MPs were installed at site FTA-2 on March 12, 1993. Monitoring points MPA, MPB, MPC were installed perpendicular to the HVW axis at respective distances of 10, 20, and 30 feet. Monitoring point MPD was installed parallel to the axis 15 feet from the west end of the HVW (see Figure 1.1). A permanent background monitoring point, MPBG was installed approximately 165 feet due east of the HVW air injection vent pipe. All permanent MP boreholes were advanced using a decontaminated hand auger. Only a single MP screen was installed per borehole. Multi-depth MP screens could not be installed at site FTA-2 as planned, since the shallow water table conditions would not provide proper construction of multiple bentonite and grout seals with adequate integrity.

The five permanent MPs were constructed using 0.5-inch diameter PVC screens and casing installed in 4-inch diameter boreholes. Each MP was constructed using a 6-inch section of 0.02-inch slotted, schedule 40 PVC screen and schedule 80 PVC casing. The screened interval was surrounded by a filter pack of 6/20 graded coarse silica sand.

Thermocouples were also installed at the screened interval of MPA-3.5 and MPD-3.5. Bentonite and grout were used to seal the annulus around each MP riser above the gravel pack. The top of each MP PVC riser was completed at ground surface with a brass gas ball valve and a 1/4-inch brass hose barb. Each MP was completed at the surface with a flush-mounted steel manhole set in a concrete 2x2-foot pad. The lid to the manhole was set approximately 3 inches above ground surface, and the concrete base was sloped toward the edges to promote drainage of surface water away from the MP. Figure 1.4 shows a typical permanent MP construction detail.

Figure 1.3



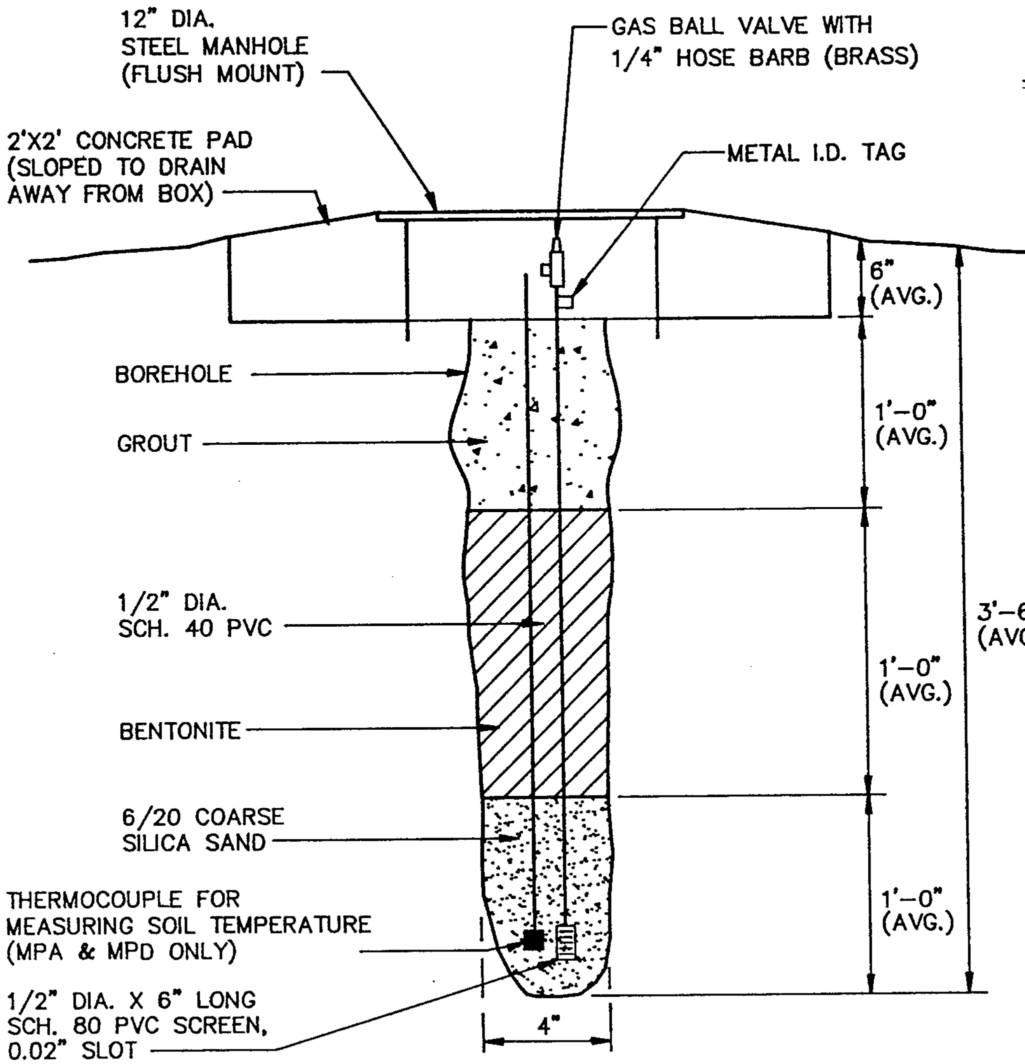
NOTES:

1. DRAWING IS NOT TO SCALE.

AS-BUILT HORIZONTAL VENTING WELL, AND TRENCH CONSTRUCTION
SITE FTA-2
FIRE TRAINING AREA

PATRICK AFB, FLORIDA

ENGINEERING-SCIENCE, INC.
Orlando, Florida



DRAWING IS NOT TO SCALE

MONITORING POINT CONSTRUCTION SPECIFICATIONS

Monitoring Point No.	Borehole Depth (FT)	Screen Interval (Feet BLS)
MPA-3.5	3.5	3.0-3.5
MPB-3.5	3.5	3.0-3.5
MPC-3.5	3.5	3.0-3.5
MPD-3.5	3.5	3.0-3.5
BACKGROUND MP-2.5	2.5	2.0-2.5

AS-BUILT PERMANENT
MONITORING POINT CONSTRUCTION DETAIL
SITE FTA-2
FIRE TRANING AREA

PATRICK AFB, FLORIDA

ENGINEERING-SCIENCE, INC.
Orlando, Florida

PA2-1-4.DWG

1.1.3 Blower Unit Installation and Operation

A 1-horsepower Gast[R] regenerative blower unit was installed at site FTA-2 for the initial and extended pilot tests. The Gast[R] blower was installed in a weatherproof enclosure and electrically wired for 120 volt, 30 amp power. A portable generator was used to conduct the air permeability and respiration tests. Patrick AFB electricians will complete permanent electrical hook up at this site for the extended 1-year test.

Air is supplied by the blower through a 4-inch diameter above ground PVC header pipe that is attached to the HVW. Figure 1.5 shows the configuration, instrumentation, and specifications for the blower and air injection system.

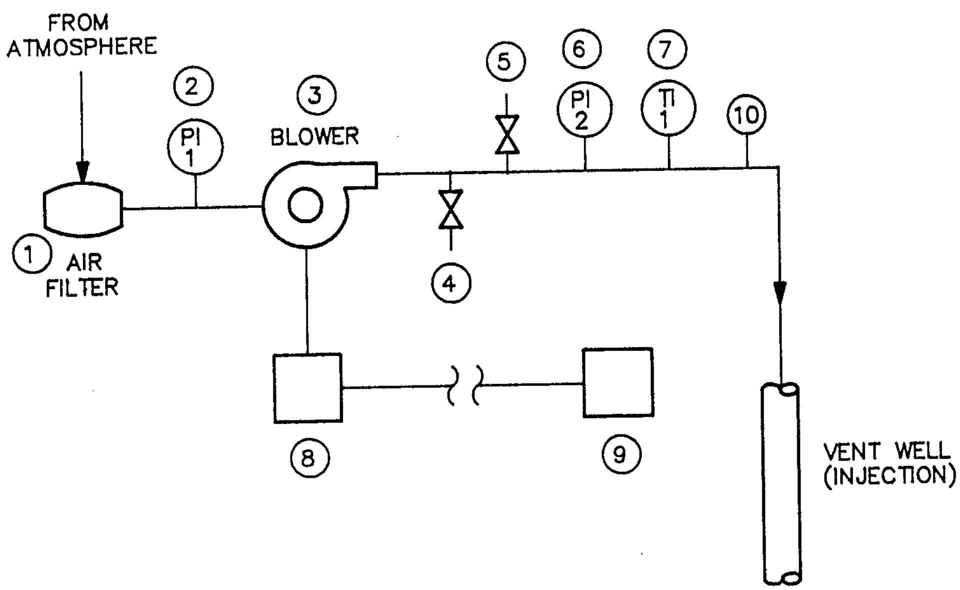
Prior to departing from the site, ES personnel will provide operations and maintenance (O & M) instructions to base personnel. A copy of the O & M checklist is provided in Appendix A.

1.2 SOIL AND SOIL GAS SAMPLING RESULTS

Soils at site FTA-2 consist of loose, fine to medium grained sand, shells, shell fragments with minor amounts of clayey sand. This soil profile was consistent from ground surface to below the water table surface, which typically averages 4 to 6 feet bls. The fine to medium sands ranged in color from white to light gray and gray, with the exception being those areas that are stained black from fuel contamination. The earthen berm, unlined fire training pit is overlain with light vegetation with some minor remnants of organic root material encountered in the upper 4 feet of the soil profile.

Soil hydrocarbon contamination at this site appears to be confined mainly within the bermed area. Contaminated soils were identified based on visual appearance, odor and volatile organic compound (VOC) field screening results. Heavily contaminated soils were encountered during the HVW trench installation and during all MP installation; the only exception being the background MP location (MPBG). Soil contamination exhibited strong hydrocarbon odors and were visibly stained from dark oily fuel. The highest concentrations of total VOCs occurred in the upper 4 feet of the soil profile. Soil gas VOC readings exceeded 20,000 parts per million, volume per volume (PPMV) of total hydrocarbons in all the MPs and HVW locations.

Figure 1.5



LEGEND

1. INLET AIR FILTER
2. VACUUM GAUGE (In H_2O)
3. BLOWER – GAST/70 SCFM @ 20 INCHES H_2O REGENERATIVE W/1HP DRIVE MOTOR
4. MANUAL PRESSURE RELIEF (BLEED) VALVE – 1 1/2" GATE
5. AUTOMATIC PRESSURE RELIEF VALVE
6. PRESSURE GAUGE (In H_2O)
7. TEMPERATURE GAUGE (°F)
8. POWER SWITCH
9. BREAKER BOX (115V/SINGLE PHASE/30 AMP)
10. AIR VELOCITY MEASURE PORT

DRAWING IS NOT TO SCALE

NOTES:

1. PERMANENT POWER WAS NOT INSTALLED AT THE TIME OF THE INTERIM PILOT TEST.

AS–BUILT BLOWER SYSTEM
FOR AIR INJECTION
SITE FTA–2
FIRE TRAINING AREA

PATRICK AFB, FLORIDA

ENGINEERING–SCIENCE, INC.
Orlando, Florida

ES

PA2–1–5.DWG

Soil samples for laboratory analysis were collected from the stainless steel hand auger bucket during the installation of the permanent MPs. Soil samples were collected from a depth of 3.5 feet at MPA and MPD locations; and from a depth of 4 feet at the center of the HVW trench location. Soil samples were screened for VOCs using a GasTech/Trace-techtor[R], hydrocarbon analyzer, to determine the presence of contamination and to select soil samples for laboratory analysis.

Soil samples were shipped via Federal Express to the ES Berkeley laboratory for chemical and physical analyses. Each of the soil samples were analyzed for the following parameters: total recoverable petroleum hydrocarbons (TRPH); benzene, toluene, ethylbenzene and xylenes (BTEX); iron; alkalinity; total Kjeldahl nitrogen (TKN); pH; phosphates; percent moisture; and grain size distribution. Soil gas samples were shipped via Federal Express to Air Toxics Inc. in Rancho Cordova, California for total volatile hydrocarbon (TVH) and BTEX analyses. The results of these analyses are presented in Table 1.1 and the chain-of-custody form is presented in Appendix C.

1.3 EXCEPTIONS TO TEST PROTOCOL DOCUMENT PROCEDURES

Test procedures described in the protocol document were used to complete treatability pilot tests at this site. Exceptions to the standard protocol document and the Bioventing Pilot Test Work Plan (Part IA) were necessary based on conditions encountered at site FTA-2. An HVW was installed due to the shallow water table at the site. Location of the permanent MPs were moved in order to monitor a larger radius of influence. Multi-depth MP screens were not installed due to the limited unsaturated soil interval at this site. Also, the bentonite seals in the MPs were hydrated in place instead of using a bentonite slurry mixture.

Soil sampling procedures were also modified from the protocol because MP boreholes were installed with a hand auger. Samples obtained for laboratory analyses were collected directly from hand auger cuttings and were not obtained using brass sampling sleeves (liners) as stated in the protocol.

1.4 FIELD QA/QC RESULTS

Field quality assurance/quality control (QA/QC) samples were not collected or required at this site.

TABLE 1.1

SOIL AND SOIL GAS LABORATORY ANALYTICAL RESULTS

Site FTA-2

Patrick AFB, Florida

Analyte (Units)[a/]	Sample Location-Depth (feet below ground surface)		
	HVW - 4	MPA - 3.5	MPD - 3.5
Soil Gas Hydrocarbons			
TPH (ppmv)	10,000	9,100	12,000
Benzene (ppmv)	ND[b/]	ND	ND
Toluene (ppmv)	ND	ND	ND
Ethylbenzene (ppmv)	1.7	1.1	1.8
Xylenes (ppmv)	5.7	3.3	6.7
Soil Hydrocarbons			
TRPH (mg/kg)	6,287	13,250	11,828
Benzene (mg/kg)	8	7.6	2.7
Toluene (mg/kg)	ND	2.4	2.7
Ethylbenzene (mg/kg)	6.4	2.4	3.1
Xylenes (mg/kg)	43	11	19
Soil Inorganics			
Iron (mg/kg)	297	238	555
Alkalinity (mg/kg as $CaCO_3$)	120	170	180
pH (units)	8.2	8.6	8.5
TKN (mg/kg)	84	47	48
Phosphates (mg/kg)	340	220	320
Soil Physical Parameters			
Soil Temperature (°F)	NS[c/]	70.4	70.3
Moisture (% wt.)	4.6	4.4	3.4
Gravel (%)	10	6	4
Sand (%)	89	91	91
Silt (%)	0.0	1	3
Clay (%)	2	2	2

a/ TRPH = total recoverable petroleum hydrocarbons; TPH = total petroleum hydrocarbons; mg/kg = milligrams per kilogram, ppmv = parts per million, volume per volume; $CaCO_3$ = calcium carbonate; TKN = total Kjeldahl nitrogen.

b/ ND = not detected.

c/ NS = not sampled.

1.5 PILOT TEST RESULTS

1.5.1 Initial Soil Gas Chemistry

Prior to initiating any air injection, all MPs were purged until oxygen levels had stabilized, and initial oxygen, carbon dioxide, and TVH concentrations were sampled using portable gas analyzers, as described in the technical protocol document (Hinchee et al., 1992). In soils surrounding each MP screened interval and at the HVW, microorganisms had completely depleted soil gas oxygen supplies, indicating significant biological activity and soil contamination. The uniformity of zero oxygen levels at this site is primarily the result of the vertical and horizontal uniformity of soil contamination. Table 1.2 describes initial soil gas chemistry at this site.

1.5.2 Air Permeability

An air permeability test was conducted according to protocol document procedures. Air was injected into the HVW for 15 minutes at a rate of approximately 70 scfm and an average pressure of 11 inches of water. Steady-state pressure levels were achieved in all MPs after only 10 minutes of air injection. Table 1.3 provides the steady-state pressures at each MP. Due to this rapid pressure response, the steady-state method of determining air permeability was selected. A soil gas permeability value of 32 darcy, typical for sandy soils, was calculated for this site. A radius of pressure influence of over 30 feet was observed.

1.5.3 Oxygen Influence

The radius of oxygen increase in the subsurface resulting from air injection into the HVW during pilot testing an important design parameter for full-scale bioventing systems. Optimization of full-scale and multiple vent well systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and vent well screen configuration.

Table 1.4 presents the change in soil gas oxygen levels that occurred during one hour of air injection. This period of air injection at approximately 70 scfm produced changes in soil gas oxygen levels throughout the 30 feet radius of the pilot testing area. Based on this rapid increase in oxygen levels, it is anticipated that the radius of influence for a long-term bioventing system at this site will exceed 30 feet. During the start up of the extended pilot test, the air injection rate will be reduced to the minimum flow required to provide oxygen within a radius of 30 feet from the HVW. Based on similar systems constructed in sandy soils, it is anticipated that an air injection rate of approximately 20 scfm will be sufficient for extended testing.

TABLE 1.2
INITIAL SOIL GAS CHEMISTRY
Site FTA-2
Patrick AFB, Florida

Sample Location	Depth (ft)	O_2(%)[d]	CO_2(%)[d]	FIELD TVH (ppmv)[a]	LAB TVH (ppmv)[b]	LAB TPH (mg/kg)[b]
MPA	3.5	0.0	7.8	>20,000	9,100	13,250
MPB	3.5	0.0	9.8	>20,000	NS	NS[c]
MPC	3.5	0.0	9.6	>20,000	NS	NS
MPD	3.5	0.0	11.3	>20,000	12,000	11,828
HVW	4	0.0	10.5	>20,000	10,000	6,287
Background	2.5	19.5	0.1	8	NS	NS

[a] Gastech/Trace-techtor field screening results.
[b] Laboratory results.
[c] NS = not sampled.
[d] Percentage based on mass of gaseous phase in vent stream.

TABLE 1.3

MAXIMUM PRESSURE RESPONSE

AIR PERMEABILITY TEST

FTA-2

PATRICK AFB, FLORIDA

	Distance from injection well (HVW) (feet)			
	10 (MPA)	20 (MPB)	30 (MPC)	15 (MPD)
Depth (feet)	3.5	3.5	3.5	3.5
Time (min)	15	15	15	15
Max Press (inches H_2O)	7.0	4.5	3.2	4.5

TABLE 1.4
INFLUENCE OF AIR INJECTION AT VENT WELL ON MONITORING POINT OXYGEN LEVELS
FTA-2
PATRICK AFB, FLORIDA

MP	Distance From VW (ft)	Depth(ft)	Initial O_2(%)	Final O_2(%) Permeability Test[a/]
A	10	3.5	0.0	18.8
B	20	3.5	0.0	4.1
C	30	3.5	0.0	0.8
D	15		0.0	14.2

a/ Reading taken at end of one hour air permeability test.

1.5.4 In Situ Respiration Rates

The *in situ* respiration test was performed by injecting a mixture of air (oxygen) and approximately 3-4 percent helium (inert tracer gas) into three MPs for a 20-hour period. Oxygen loss and other changes in soil gas composition over time were then measured at each MP. Oxygen, TVH, carbon dioxide, and helium were measured for a period of approximately 65 hours following air injection. The measured oxygen losses were then used to calculate biological oxygen utilization rates. The results of *in situ* respiration testing for MPA, MPB, and MPD are presented in Figures 1.6 through 1.8. Table 1.5 provides a summary of the oxygen utilization rates.

Because helium is a conservative, inert gas, the change in helium concentrations over time can be useful in determining the effectiveness of the bentonite seals above MP screened intervals. Figures 1.6 through 1.8 compare oxygen utilization and helium retention. Because the observed helium loss was negligible, and because helium will diffuse approximately three times faster than oxygen due to oxygen's greater molecular weight, the measured oxygen loss at these MPs is the result of bacterial respiration and not due to oxygen diffusion or oxygen loss from leaks in the MPs.

Oxygen loss occurred at moderate rates, ranging from 0.005 percent per minute at MPD to .007 percent per minute at MPA. Based on these oxygen utilization rates, an estimated 1100 to 2,290 milligrams (mg) of fuel per kilogram (kg) of soil can be degraded each year at this site. This estimate is based on an average air-filled porosity of approximately 0.15 liter per kg of soil, and a conservative ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. Additional information on the calculations for fuel biodegradation can be found in Section 5 of the protocol. Actual rates will vary and could be reduced during the rainy season due to higher soil moisture and reduced air-filled porosity.

1.5.5 Potential For Air Emissions

The long-term potential for air emissions from full-scale bioventing operations at this site is considered low because of the low initial BTEX levels (<10ppm) in the site soil gas and the low injection rate proposed for extended testing. Health and safety monitoring was conducted during the one hour air permeability test using a GasTech[R] Total Hydrocarbon Analyzer sensitive to 1 ppm increases in volatile hydrocarbons. No sustained emissions in excess of 1 ppm were detected in the breathing zone. Because the potential for air emissions is highest during this initial

Figure 1.6

Respiration Test
Oxygen and Helium Concentrations
FTA-2 MPA
Patrick AFB, FL

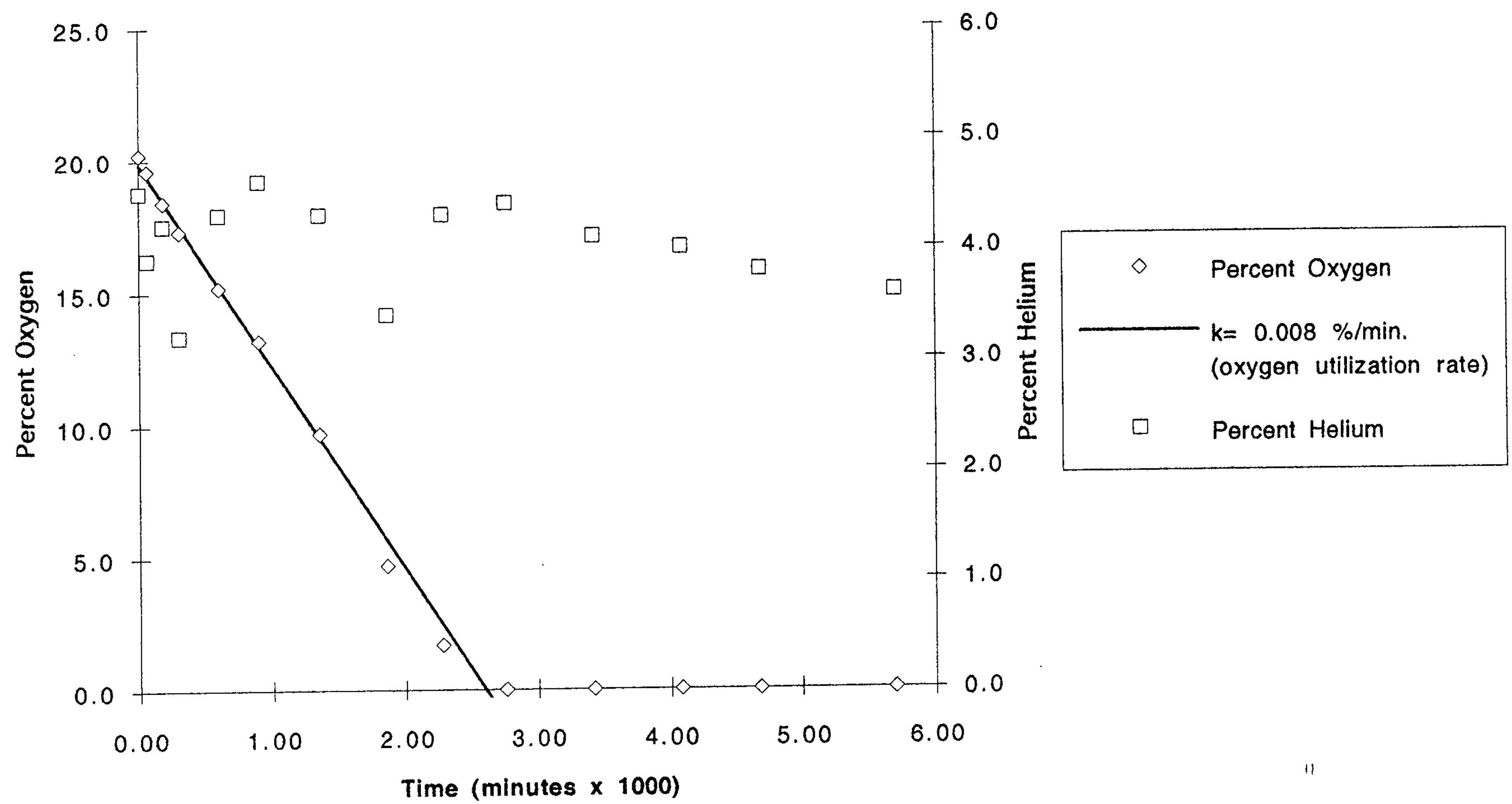


Figure 1.7

Respiration Test
Oxygen and Helium Concentrations
FTA-2 MPB
Patrick AFB, FL

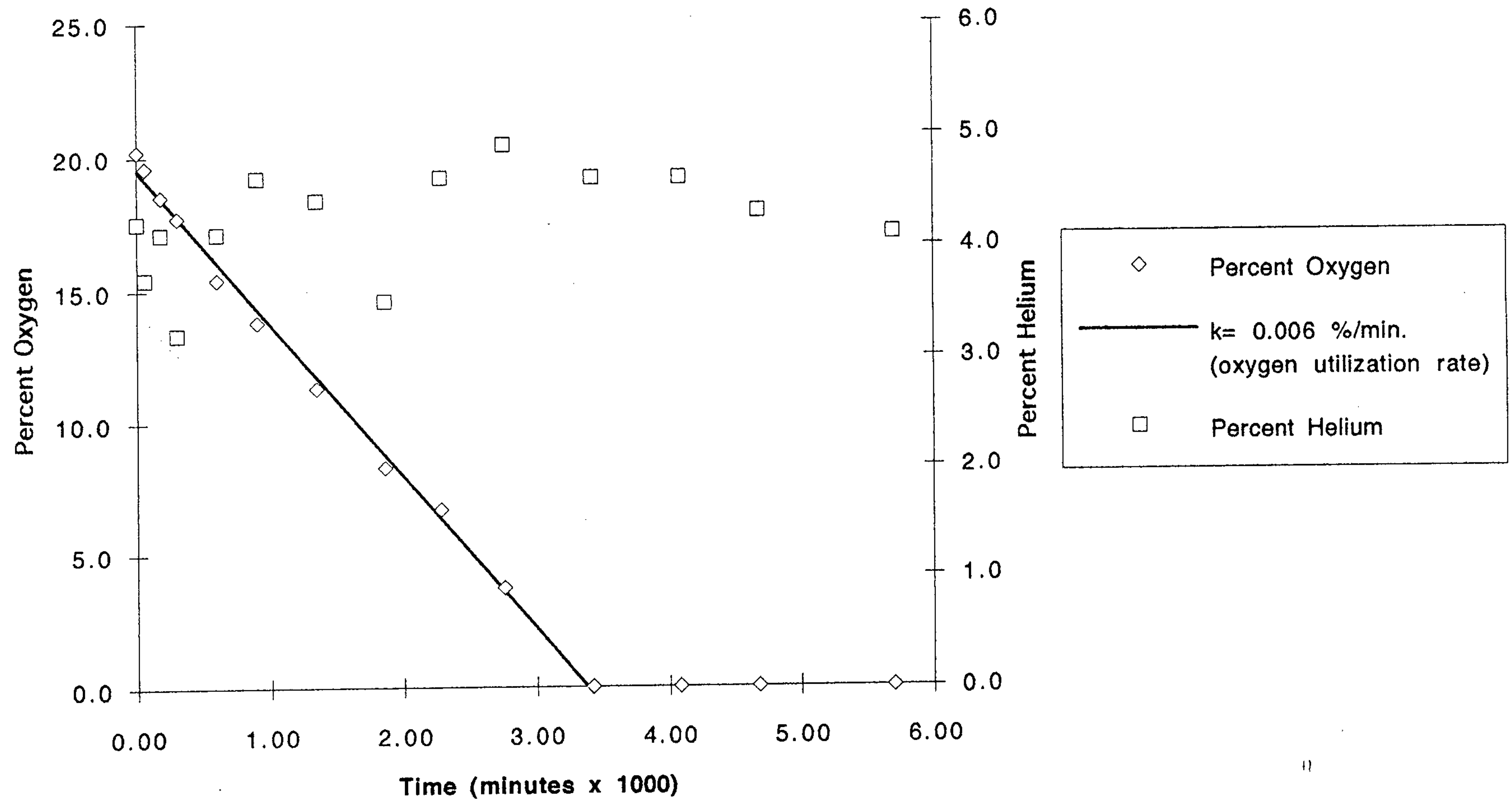


Figure 1.8

Respiration Test
Oxygen and Helium Concentrations
FTA-2 MPD
Patrick AFB, FL

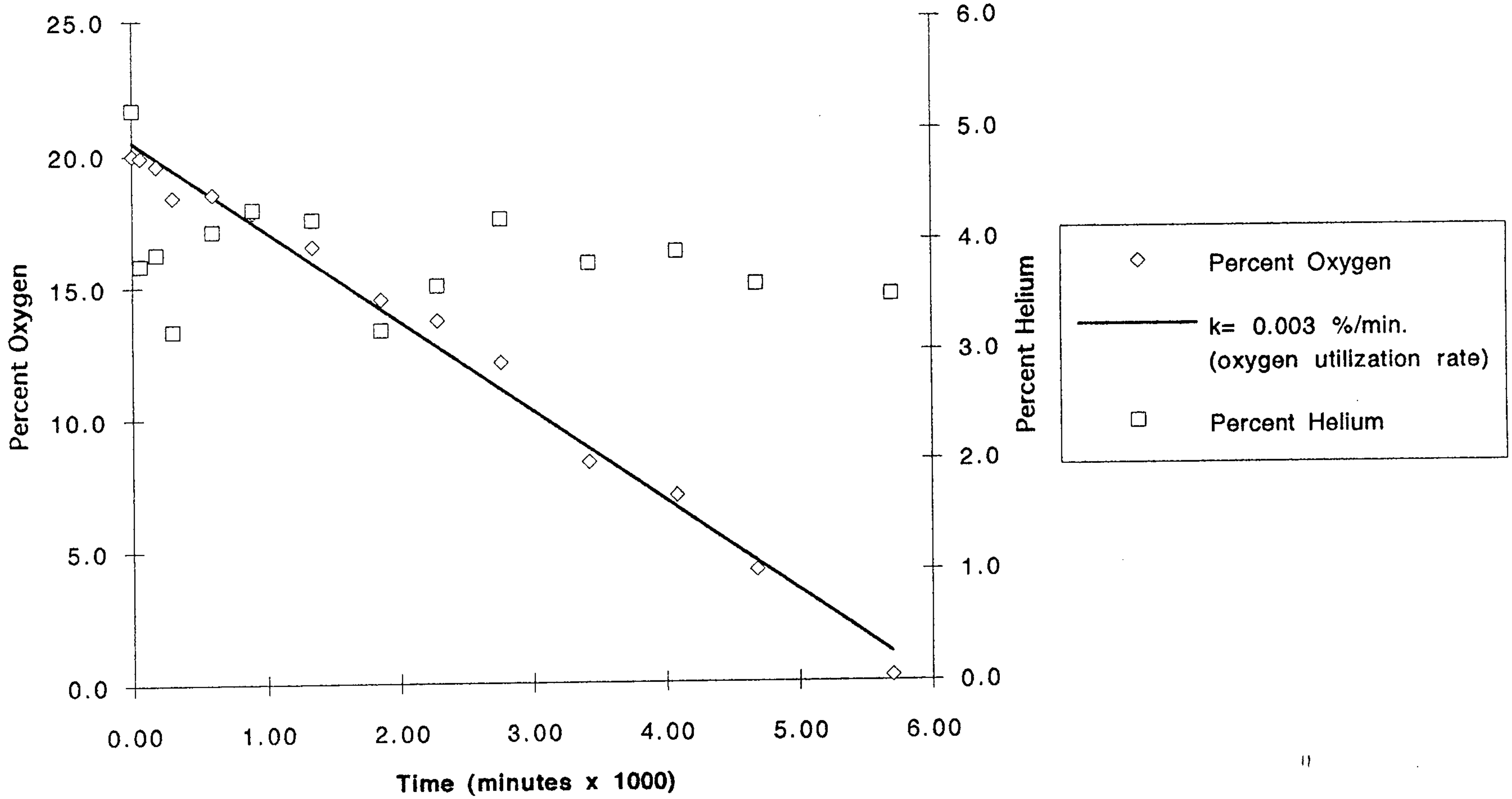


TABLE 1.5
OXYGEN UTILIZATION RATES
FTA-2
PATRICK AFB, FLORIDA

Location	O_2 Loss[a/] (%)	Test[b/] Duration (min)	O_2 Utilization[c/] Rate (%/min)
MPA	20.2	2760	0.008
MPB	20.0	3420	0.006
MPD	20.0	5760	0.003

a/ Actual measured oxygen loss.
b/ Elapsed time from beginning of test to time when minimum oxygen concentration was measured.
c/ Values based on best-fit lines (Figures 1.6 through 1.8).

hour of air injection, the long-term emission potential is considered low. The site is relatively isolated and located several hundred feet from any occupied building or work area.

2.0 BX SERVICE STATION, PATRICK AFB

2.1 Pilot Test Design and Construction

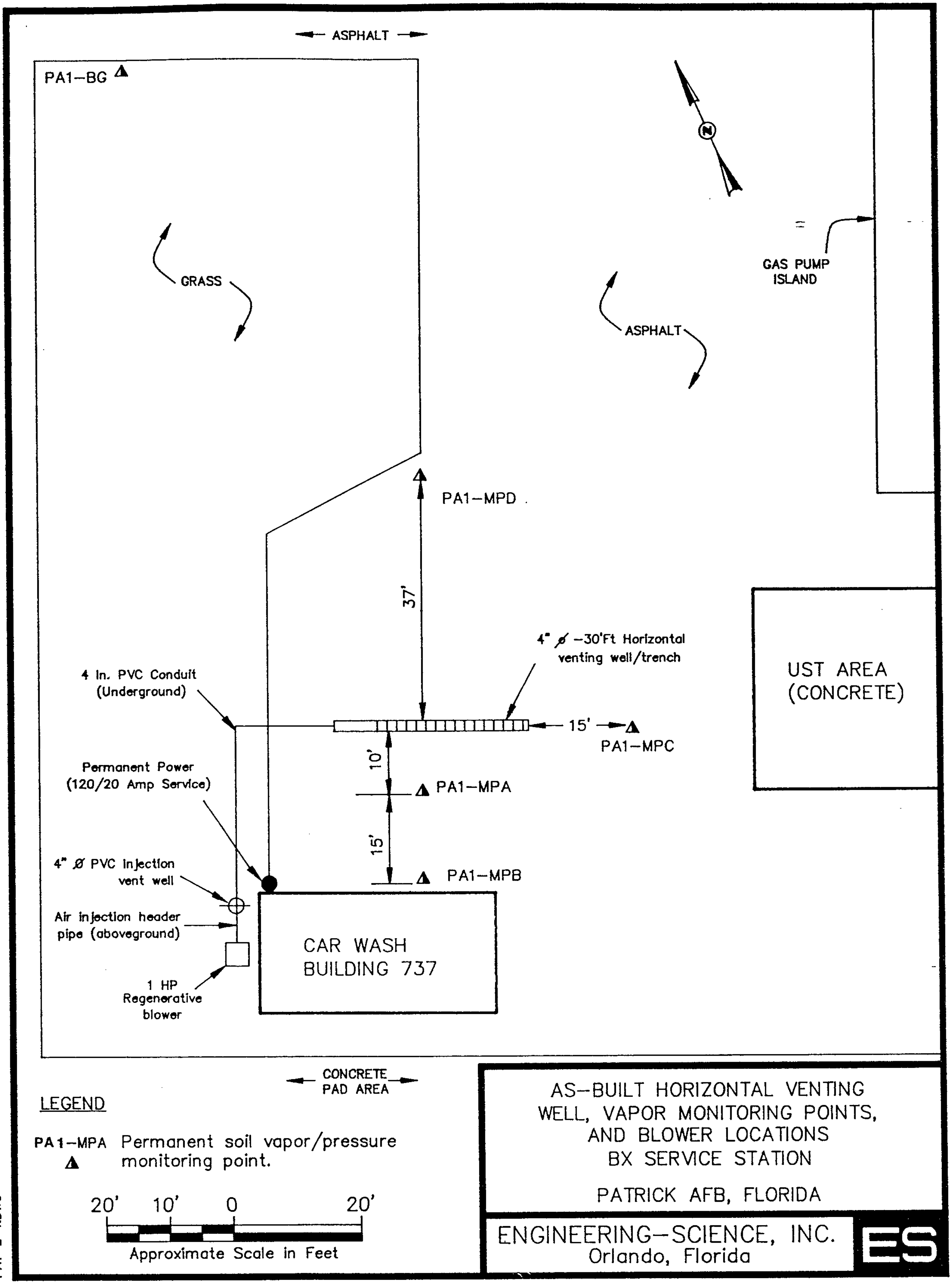
The following sections describe the final design and installation of the bioventing system at the BX Service Station site. A horizontal trench and air injection venting well (HVW) was installed on March 9 and 10, 1993 by Engineering-Science, Inc. (ES) Orlando, Florida and a subcontractor, Groundwater Protection, Inc. (Remediation Division) of Orlando, Florida. Five permanent pressure/vapor monitoring points (MPs) were installed on March 9, 1993. The HVW construction, MP installations, and soil sampling were directed by Mr. Steve Archabal, the ES site manager. The following sections describe in more detail the final design, installation, and testing of the bioventing system at this site.

One HVW, five permanent MPs, and a blower unit in a weather-proof enclosure were installed at the BX Service Station site. A single-depth MP construction was used at the site. A monitoring depth screen interval of 3.0 to 3.5 feet below land surface (bls) was installed, due to shallow water table conditions of approximately 5.0 feet bls at this site. Figure 2.1 depicts the test area with the locations of the MPs, HVW, and blower at the BX Service Station. Figure 2.2 shows a hydrogeologic cross section in a north-south direction, perpendicular to the axis of the HVW.

2.1.1 Horizontal Air Injection Venting Well Construction

The HVW was installed within the area of the soil gas survey performed at this site on January 12, 1993. Orientation of the HVW trench axis is in an east-west direction, and was constructed in a shallow trench excavated in visibly contaminated, oxygen-depleted soils. Soils in the immediate vicinity of the trench emitted hydrocarbon odors.

An HVW was installed at this site because of the relatively shallow water table, which prevented the proper installation of a vertical vent well (VW) according to typical AFCEE work plan protocols (Hinchee et al., 1992). Figure 2.3 shows the as-built construction details of the trench and HVW. On the date of the HVW/trench installation, water level at the BX Service Station site was approximately 5.0 feet bls. According to previous IRP reports for this site, water level elevations can vary between 4 and 6 feet bls. Consequently, the installation depth of the HVW/trench was in accordance with the proposed depth in the Bioventing Pilot Test Work Plan (see Part IB).

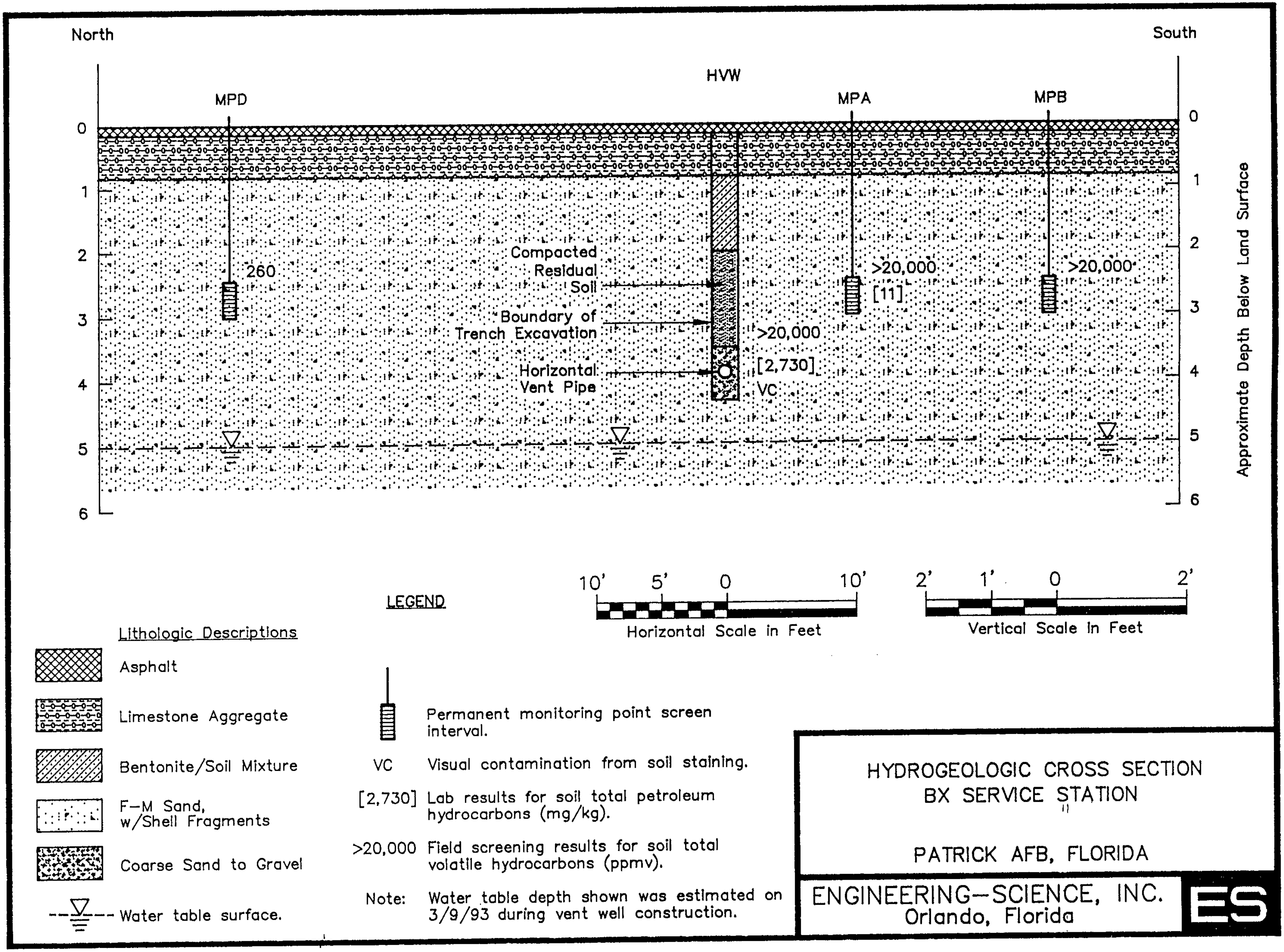


AS–BUILT HORIZONTAL VENTING WELL, VAPOR MONITORING POINTS, AND BLOWER LOCATIONS
BX SERVICE STATION

PATRICK AFB, FLORIDA

ENGINEERING–SCIENCE, INC.
Orlando, Florida

Figure 2.2


North
South
HVW
MPD
MPA
MPB
260
>20,000
[11]
>20,000
Compacted Residual Soil
Boundary of Trench Excavation
Horizontal Vent Pipe
>20,000
[2,730]
VC
Approximate Depth Below Land Surface
0
1
2
3
4
5
6
10'
5'
0
10'
Horizontal Scale in Feet
2'
1'
0
2'
Vertical Scale in Feet
LEGEND
Lithologic Descriptions
Asphalt
Limestone Aggregate
Bentonite/Soil Mixture
F–M Sand, w/Shell Fragments
Coarse Sand to Gravel
Water table surface.
Permanent monitoring point screen interval.
VC Visual contamination from soil staining.
[2,730] Lab results for soil total petroleum hydrocarbons (mg/kg).
>20,000 Field screening results for soil total volatile hydrocarbons (ppmv).
Note: Water table depth shown was estimated on 3/9/93 during vent well construction.
HYDROGEOLOGIC CROSS SECTION
BX SERVICE STATION
PATRICK AFB, FLORIDA
ENGINEERING–SCIENCE, INC.
Orlando, Florida
ES

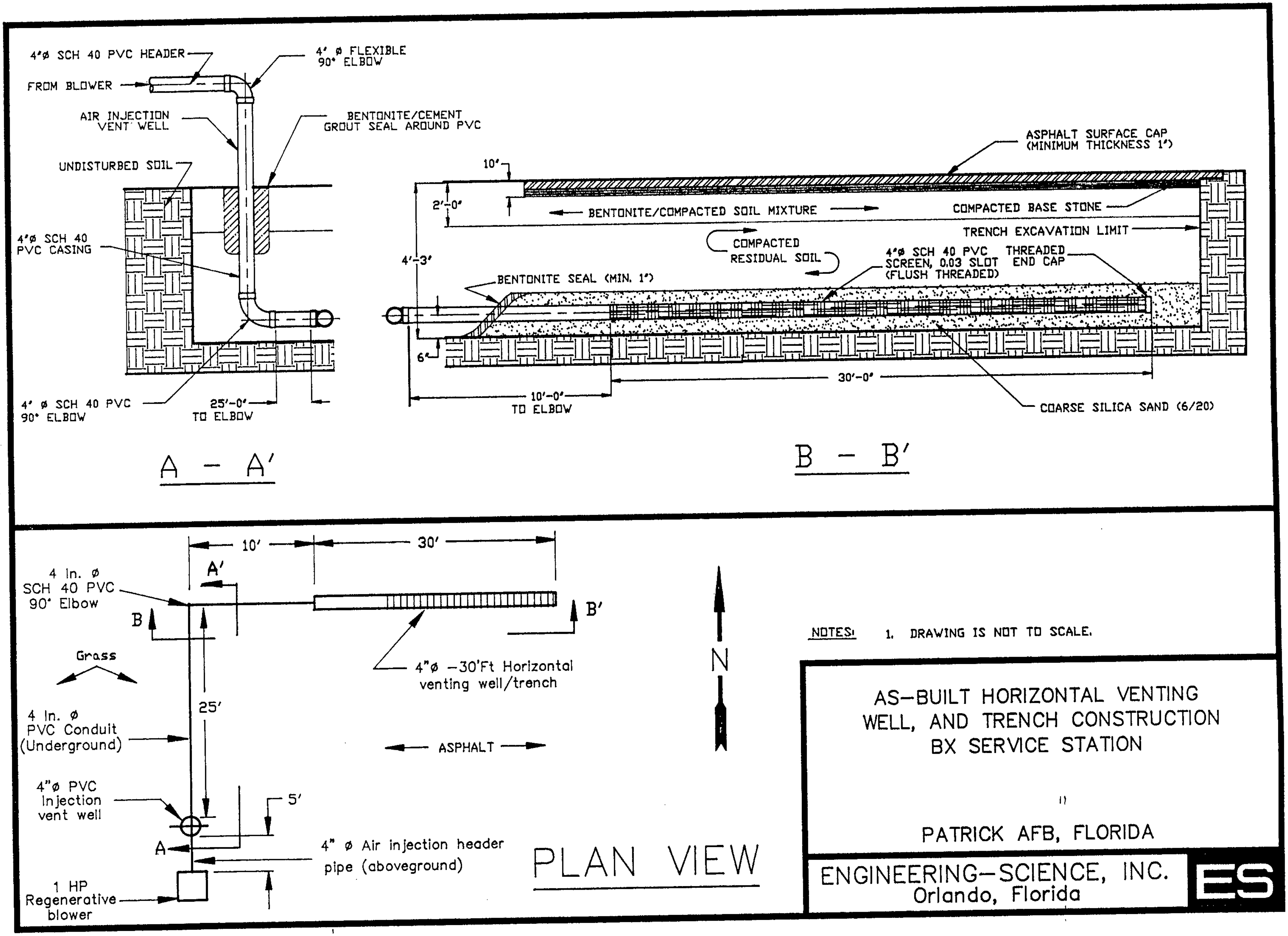

4"ø SCH 40 PVC HEADER
FROM BLOWER
4' ø FLEXIBLE 90° ELBOW
AIR INJECTION VENT WELL
BENTONITE/CEMENT GROUT SEAL AROUND PVC
UNDISTURBED SOIL
4"ø SCH 40 PVC CASING
4' ø SCH 40 PVC 90° ELBOW
25'-0" TO ELBOW
A - A'
ASPHALT SURFACE CAP (MINIMUM THICKNESS 1")
10"
2'-0"
BENTONITE/COMPACTED SOIL MIXTURE
COMPACTED BASE STONE
TRENCH EXCAVATION LIMIT
COMPACTED RESIDUAL SOIL
4'-3'
4"ø SCH 40 PVC SCREEN, 0.03 SLOT (FLUSH THREADED)
THREADED END CAP
BENTONITE SEAL (MIN. 1")
6"
30'-0"
10'-0" TO ELBOW
COARSE SILICA SAND (6/20)
B - B'
10'
30'
4 In. ø SCH 40 PVC 90° Elbow
A'
B
B'
Grass
4"ø -30'Ft Horizontal venting well/trench
N
25'
4 In. ø PVC Conduit (Underground)
ASPHALT
4"ø PVC Injection vent well
5'
A
4" ø Air injection header pipe (aboveground)
1 HP Regenerative blower
PLAN VIEW
NOTES: 1. DRAWING IS NOT TO SCALE.
AS-BUILT HORIZONTAL VENTING WELL, AND TRENCH CONSTRUCTION BX SERVICE STATION
PATRICK AFB, FLORIDA
ENGINEERING-SCIENCE, INC. Orlando, Florida
ES

Figure 2.3

A backhoe equipped with a 12-inch wide bucket was used for the trench excavation. A 16-inch wide x 40-foot long area of asphalt was saw cut and removed in order to prepare the site, prior to the trench excavation. The excavation was then completed to 4-feet 3-inches bls for a total distance of approximately 70 feet, as shown in Figure 2.1.

The subsurface soils encountered at this site are predominantly unconsolidated; comprised of fine to medium grained quartz sand, shells, and shell fragments. Due to the loose nature of the soil, a maximum depth of 4-feet 3-inches was completed to prevent the possibility of a cave-in during the installation of the HVW.

Upon completing the trench excavation, the HVW was constructed using 4-inch diameter, schedule 40 polyvinyl chloride (PVC) screen and casing. A 30-foot section of 0.03-inch slotted screen and 40 feet of threaded casing were installed in the excavation. The screen section was surrounded by a coarse graded (6/20) silica sand in the form of a gravel envelope. Two PVC elbows equipped with 200 pounds-per-square-inch (PSI) rubber gaskets were used to connect the horizontal sections of venting pipe and to connect a vertical 4-inch diameter PVC riser pipe to the ground surface. The gravel pack was overlain by residual soil and compacted in 1-foot lifts with a tamp to help minimize vertical air losses/short-circuiting to the surface. A 1-foot layer of residual soil and bentonite mixture was placed on top of the compacted soil in three 4-inch lifts and hydrated thoroughly between lifts. A 10-inch layer of limerock base stone was placed over the bentonite/soil mixture and compacted in place. A 1 to 2-inch layer of asphalt was placed over the limerock base to complete the surface cap. Figures 2.2 and 2.3 depict the various layers and surface cap discussed in trench construction.

2.1.2 Permanent Monitoring Points

Five permanent MPs were installed at the BX Service Station on March 9, 1993. Monitoring points MPA, MPB, MPD were installed perpendicular to the HVW axis at respective distances of 10, 25, and 37 feet. Monitoring point MPC was installed parallel to the axis 15 feet from the east end of the HVW (see Figure 2.1). A permanent background monitoring point, MPBG was installed 65 feet north and 42 feet west of the MPD location. All permanent MP boreholes were advanced using a decontaminated hand auger. A single MP screen was installed per borehole as outlined in the Bioventing Work Plan found in Part IB of this report.

The five permanent MPs were constructed using 0.5-inch diameter PVC screens and casing installed in 4-inch diameter boreholes. Each MP was constructed using a 6-inch section of 0.02-inch slotted, schedule 40 PVC screen and schedule 80 PVC

casing. The screened interval was surrounded by a filter pack of 6/20 graded coarse silica sand.

Thermocouples were also installed at the screened interval of MPA-3.5, MPC-3.5, and background MP locations. Bentonite and grout were used to seal the annulus around each MP riser above the gravel pack. The top of each MP PVC riser was completed at ground surface with a brass gas ball valve and a 1/4-inch brass hose barb. Each MP was completed at the surface with a flush-mounted steel manhole set in a concrete 2x2-foot pad. The lid to the manhole was set approximately 1-inch above ground surface, and the concrete base was sloped toward the edges to promote drainage of surface water away from the MP. Figure 2.4 shows a typical permanent MP construction detail.

2.1.3 Blower Unit Installation and Operation

A 1-horsepower Gast[R] regenerative blower unit was installed at the BX Service Station for the initial and extended pilot tests. The Gast[R] blower was installed in a weatherproof enclosure and electrically wired for 120 volt, 30 amp power. Permanent power was available to conduct the air permeability and respiration tests, and will be used for the extended 1-year test.

Air is supplied by the blower through a 4-inch diameter above ground PVC header pipe that is attached to the HVW. Figure 2.5 shows the configuration, instrumentation, and specifications for the blower and air injection system.

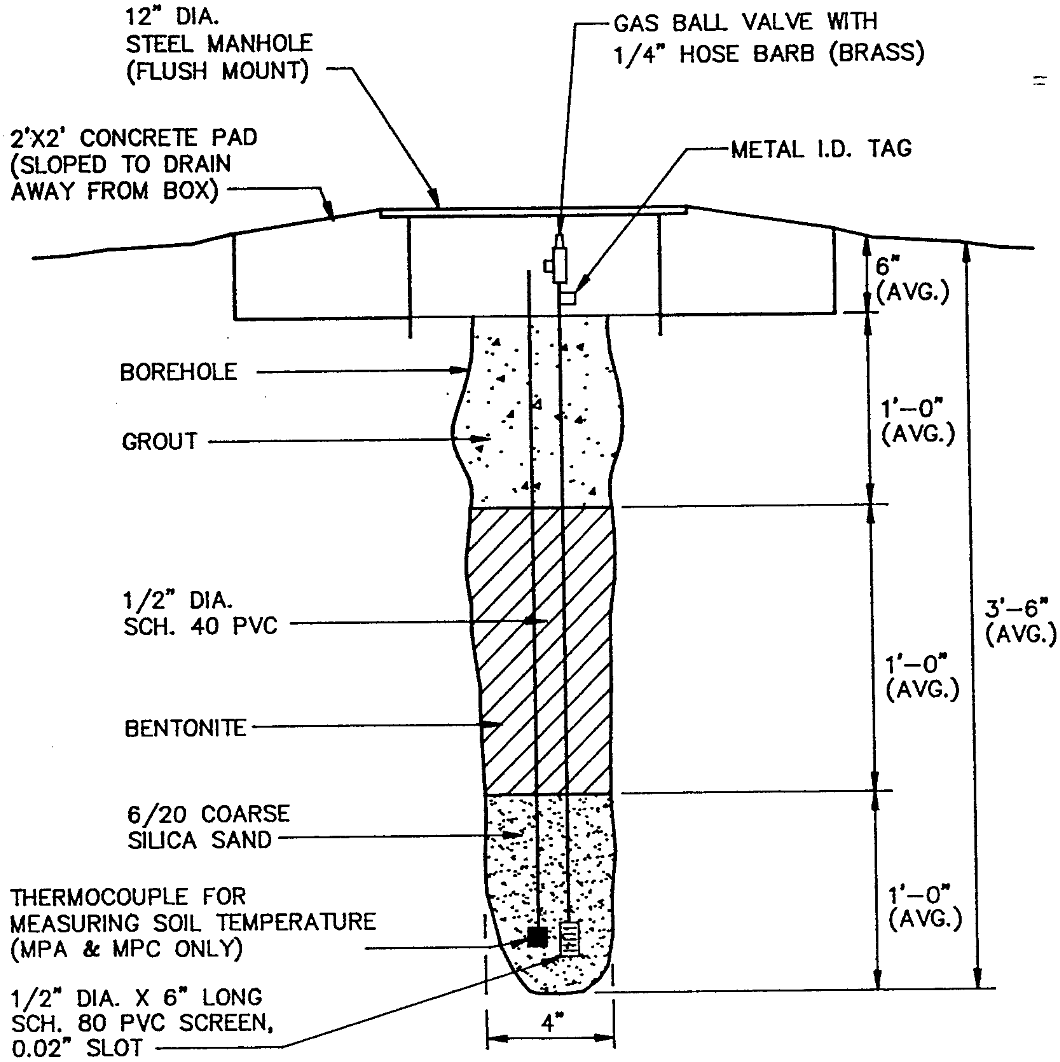
Prior to extending testing, ES personnel will provide operations and maintenance (O & M) instructions to base personnel. A copy of the O & M checklist is provided in Appendix A.

2.2 SOIL AND SOIL GAS SAMPLING RESULTS

Soils at the BX Service Station consist of loose, fine to medium grained sand, shells, shell fragments. This soil profile was consistent throughout the unsaturated zone and to below the water table surface, which typically averages 4 to 6 feet bls. The fine to medium sands ranged in color from white to light gray and gray.

Soil hydrocarbon contamination at this site appears to extend throughout most of the 40x40 foot study area. Contaminated soils were identified based on visual appearance, odor and volatile organic compound (VOC) field screening results. Heavily contaminated soils were encountered during the HVW trench and MP installations; the only exception being the background MP and MPD locations. Areas where soil contamination was encountered exhibited hydrocarbon fuel odors, and contained high VOC concentrations. High concentrations of total VOCs

Figure 2.4



DRAWING IS NOT TO SCALE

MONITORING POINT CONSTRUCTION SPECIFICATIONS

Monitoring Point No.	Borehole Depth (FT)	Screen Interval (Feet BLS)
MPA-3.5	3.5	3.0-3.5
MPB-3.5	3.5	3.0-3.5
MPC-3.5	3.5	3.0-3.5
MPD-3.5	3.5	3.0-3.5
BACKGROUND MP-3.5	3.5	3.0-3.5

AS-BUILT PERMANENT
MONITORING POINT CONSTRUCTION DETAIL
BX SERVICE STATION

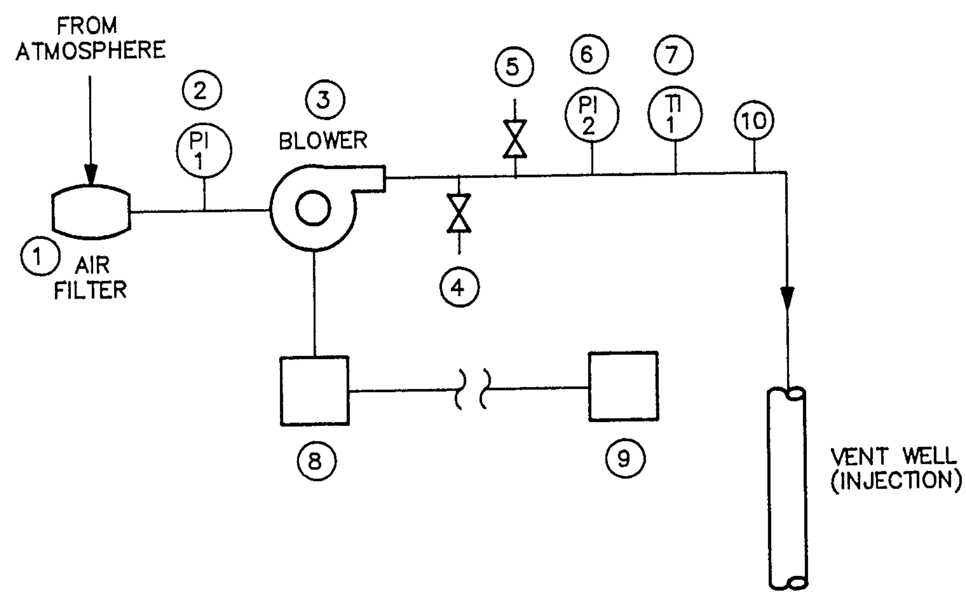
PATRICK AFB, FLORIDA

ENGINEERING-SCIENCE, INC.
Orlando, Florida

ES

PA1-2-4.DWG

Figure 2.5



LEGEND

1. INLET AIR FILTER
2. VACUUM GAUGE (In H_2O)
3. BLOWER – GAST/70 SCFM @ 20 INCHES H_2O REGENERATIVE W/1HP DRIVE MOTOR
4. MANUAL PRESSURE RELIEF (BLEED) VALVE – 1 1/2" GATE
5. AUTOMATIC PRESSURE RELIEF VALVE
6. PRESSURE GAUGE (In H_2O)
7. TEMPERATURE GAUGE (°F)
8. POWER SWITCH
9. BREAKER BOX (120V/SINGLE PHASE/20 AMP)
10. AIR VELOCITY MEASURE PORT

DRAWING IS NOT TO SCALE

AS–BUILT BLOWER SYSTEM
FOR AIR INJECTION
BX SERVICE STAION

PATRICK AFB, FLORIDA

ENGINEERING–SCIENCE, INC.
Orlando, Florida

PA1–2–5.DWG

occurred throughout the unsaturated soils. Soil gas VOC readings, using field instruments, exceeded 20,000 parts per million, volume per volume (PPMV) of total hydrocarbons at MPA, MPB, MPC, and HVW locations.

Soil samples for laboratory analysis were collected from the stainless steel hand auger bucket during the installation of the permanent MPs. Soil samples were collected from a depth of 3.5 feet at MPA and MPC locations; and from a depth of 4.5 feet at the center of the HVW trench location. Soil samples were screened for VOCs using a GasTech/Trace-techtor[R], hydrocarbon analyzer, to determine the presence of contamination and to select soil samples for laboratory analysis.

Soil samples were shipped via Federal Express to the ES Berkeley laboratory for chemical and physical analyses. Each of the soil samples were analyzed for the following parameters: total recoverable petroleum hydrocarbons (TRPH); benzene, toluene, ethylbenzene and xylenes (BTEX); iron; alkalinity; total Kjeldahl nitrogen (TKN); pH; phosphates; percent moisture; and grain size distribution. Soil gas samples were shipped via Federal Express to Air Toxics Inc. in Rancho Cordova, California for total volatile hydrocarbon (TVH) and BTEX analyses. The results of these analyses are presented in Table 2.1 and the chain-of-custody form is presented in Appendix C.

2.3 EXCEPTIONS TO TEST PROTOCOL DOCUMENT PROCEDURES

Test procedures described in the protocol document were used to complete treatability pilot tests at this site. Exceptions to the standard protocol document and the Bioventing Pilot Test Work Plan (Part IB) were necessary based on conditions encountered at the BX Service Station. An HVW was installed due to the shallow water table at the site. The bentonite seals in the MPs were hydrated in place instead of using a bentonite slurry mixture.

Soil sampling procedures were also modified from the protocol because MP boreholes were installed with a hand auger. Samples obtained for laboratory analyses were collected directly from hand auger cuttings and were not obtained using brass sampling sleeves (liners) as stated in the protocol.

2.4 FIELD QA/QC RESULTS

Field quality assurance/quality control (QA/QC) samples were not collected or required at this site.

TABLE 2.1

SOIL AND SOIL GAS LABORATORY ANALYTICAL RESULTS

BX Service Station

Patrick AFB, Florida

Analyte (Units)[a]	Sample Location-Depth (feet below ground surface)		
	HVW - 4	MPA - 3.5	MPC - 3.5
Soil Gas Hydrocarbons			
TPH (ppmv)	47,000	100,000	38,000
Benzene (ppmv)	ND[b]	ND	ND
Toluene (ppmv)	15	110	8.3
Ethylbenzene (ppmv)	14	46	12
Xylenes (ppmv)	200	310	83
Soil Hydrocarbons	HVW - 4.5		
TRPH (mg/kg)	2,730	11	60
Benzene (mg/kg)	ND	ND	ND
Toluene (mg/kg)	56	23	ND
Ethylbenzene (mg/kg)	260	320	ND
Xylenes (mg/kg)	2,500	140	5.7
Soil Inorganics			
Iron (mg/kg)	513	464	334
Alkalinity (mg/kg as $CaCO_3$)	300	210	150
pH (units)	8.7	8.8	8.8
TKN (mg/kg)	46	25	24
Phosphates (mg/kg)	250	220	300
Soil Physical Parameters			
Soil Temperature (°F)	NS[c]	76.2	77.4
Moisture (% wt.)	15	2.9	1.9
Gravel (%)	2	1	1
Sand (%)	96	96	96
Silt (%)	0.0	0	0
Clay (%)	2	3	3

a/ TRPH = total recoverable petroleum hydrocarbons; TPH = total petroleum hydrocarbons; mg/kg = milligrams per kilogram, ppmv = parts per million, volume per volume; $CaCO_3$ = calcium carbonate; TKN = total Kjeldahl nitrogen.

b/ ND = not detected.

c/ NS = not sampled.

2.5 PILOT TEST RESULTS

2.5.1 Initial Soil Gas Chemistry

Prior to initiating any air injection, all MPs were purged until oxygen levels had stabilized, and initial oxygen, carbon dioxide, and TVH concentrations were sampled using portable gas analyzers, as described in the technical protocol document. Table 2.2 describes initial soil gas chemistry at the site. At MPA, MPB and MPC and at the HVW, microorganisms had completely depleted soil gas oxygen supplies, indicating significant biological activity and soil contamination. The asphalt cover over this area also prevents resupply (natural diffusion) of oxygen from the atmosphere. Initial oxygen levels at MPD were much higher indicating that this area has little or no contamination. Soil gas TVH levels at MPD were significantly lower than other site locations. A background MPBG located approximately 110 feet northwest from the center of the spill had near atmospheric levels of oxygen and carbon dioxide. This indicates that uncontaminated soils do not exert any significant oxygen demand due to natural organic biodegradation or abiotic reactions.

2.5.2 Air Permeability

An air permeability test was conducted according to protocol document procedures. Air was injected into the HVW for 10 minutes at a rate of approximately 70 scfm and an average pressure of 10 inches of water. Steady-state pressure levels were achieved in all MPs after only 5 minutes of air injection. Table 2.3 provides the steady-state pressures at each MP. Due to this rapid pressure response, the steady-state method of determining air permeability was selected. A soil gas permeability value of 22 darcy, typical for sandy soils, was calculated for this site. A radius of pressure influence of over 37 feet was observed at this site.

2.5.3 Oxygen Influence

The radius of oxygen increase in the subsurface resulting from air injection into the HVW during pilot testing is an important design parameter for full-scale bioventing systems. Optimization of full-scale and multiple vent well systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and vent well screen configuration.

Table 2.4 presents the change in soil gas oxygen levels that occurred after one hour of continuous air injection. This period of air injection, at approximately 70 scfm, produced changes in soil gas oxygen levels at least 37 feet from the HVW. While oxygen level increased at MPA, MPB, and MPC, an oxygen decrease was observed in MPD. This decrease is caused by oxygen depleted soil gas moving

TABLE 2.2
INITIAL SOIL GAS CHEMISTRY
BX Service Station
Patrick AFB, Florida

Sample Location	Depth (ft)	O_2(%)[d]	CO_2(%)[d]	FIELD TVH (ppmv)[a]	LAB TVH (ppmv)[b]	LAB TPH (mg/kg)[b]
MPA	3.5	0.0	14.3	>20,000	100,000	11
MPB	3.5	0.0	13.6	>20,000	NS	NS[c]
MPC	3.5	0.0	15.2	>20,000	38,000	60
MPD	3.5	15.9	2.8	260	NS	NS
HVW	4	0.0	15	>20,000	47,000	2,730
Background	2.5	19.3	0.5	95	NS	NS

[a] Gastech/Trace-techtor field screening results.
[b] Laboratory results.
[c] NS = not sampled.
[d] Percentage based on mass of gaseous phase in vent stream.

TABLE 2.3

MAXIMUM PRESSURE RESPONSE

AIR PERMEABILITY TEST

BX SERVICE STATION

PATRICK AFB, FLORIDA

Distance from injection well (HVW) (feet)	10 (MPA)	25 (MPB)	15 (MPC)	37 (MPD)
Depth (feet)	3.5	3.5	3.5	3.5
Time (min)	10	10	10	10
Max Press. (inches H_2O)	6.2	3.3	2.6	0.70

TABLE 2.4
INFLUENCE OF AIR INJECTION AT VENT WELL ON MONITORING POINT OXYGEN LEVELS
BX SERVICE STATION
PATRICK AFB, FLORIDA

MP	Distance From HVW (ft)	Depth(ft)	Initial O_2(%)	Final O_2(%) Permeability Test[a/]
A	10	3.5	0.0	20.3
B	25	3.5	0.0	8.2
C	15	3.5	0.0	19.5
D	37	3.5	15.9	13.7

a/ Reading taken at end of one hour air permeability test.

outward from the center of the spill area. Based on this rapid change in oxygen levels, it is anticipated that the radius of oxygen influence for a long-term bioventing system at this site will exceed 37 feet.

Due to the volatile nature of gasoline contaminated soil gas, Engineering-Science has selected a low rate of air extraction as the means of drawing in oxygenated soil gas from surrounding clean soils during the initial months of extended pilot testing operations. An additional advantage of this technique is the positive control of vapors away from nearby buildings. During the start up of the extended pilot test, the air extraction rate will be set at approximately 30 scfm to remove the initial high soil vapor concentrations and to provide at least 5 percent oxygen to all MPs. Treatment of extracted soil gas is discussed in Section 2.5.5. Once the soil vapor concentrations are reduced to less than 1000 ppmv, the blower will be reversed and air will be injected at a rate of approximately 10 scfm to promote in situ biodegradation of the remaining fuel residuals.

2.5.4 In Situ Respiration Rates

The *in situ* respiration test was performed by injecting a mixture of air (oxygen) and approximately 3-4 percent helium (inert tracer gas) into MPA, MPB, and MPC for a 20-hour period. Oxygen loss and other changes in soil gas composition over time were then measured at each MP. Oxygen, TVH, carbon dioxide, and helium were measured for a period of approximately 120 hours following air injection. The measured oxygen losses were then used to calculate biological oxygen utilization rates. The results of *in situ* respiration testing for MPA, MPB, and MPC are presented in Figures 2.6 through 2.8. Table 2.5 provides a summary of the oxygen utilization rates.

Because helium is a conservative, inert gas, the change in helium concentrations over time can be useful in determining the effectiveness of the bentonite seals above MP screened intervals. Figures 2.6 through 2.8 compare oxygen utilization and helium retention. Although the helium recovery at this site was erratic, the loss of helium from the soil was less that the steady rate of oxygen utilization. Because helium will diffuse approximately three times faster than oxygen due to oxygen's greater molecular weight, the measured oxygen loss is primarily the result of bacterial respiration and not due to oxygen diffusion or oxygen loss from leaks in the MPs.

Oxygen loss occurred at very consistent and moderate rates at this site. Soils surrounding each of the three MPs utilized oxygen at a rate of 0.003 percent per minute. Based on this oxygen utilization rate, an estimated 900 milligrams (mg) of

Figure 2.6

Respiration Test
Oxygen and Helium Concentrations
BX Service Station MPA
Patrick AFB, FL

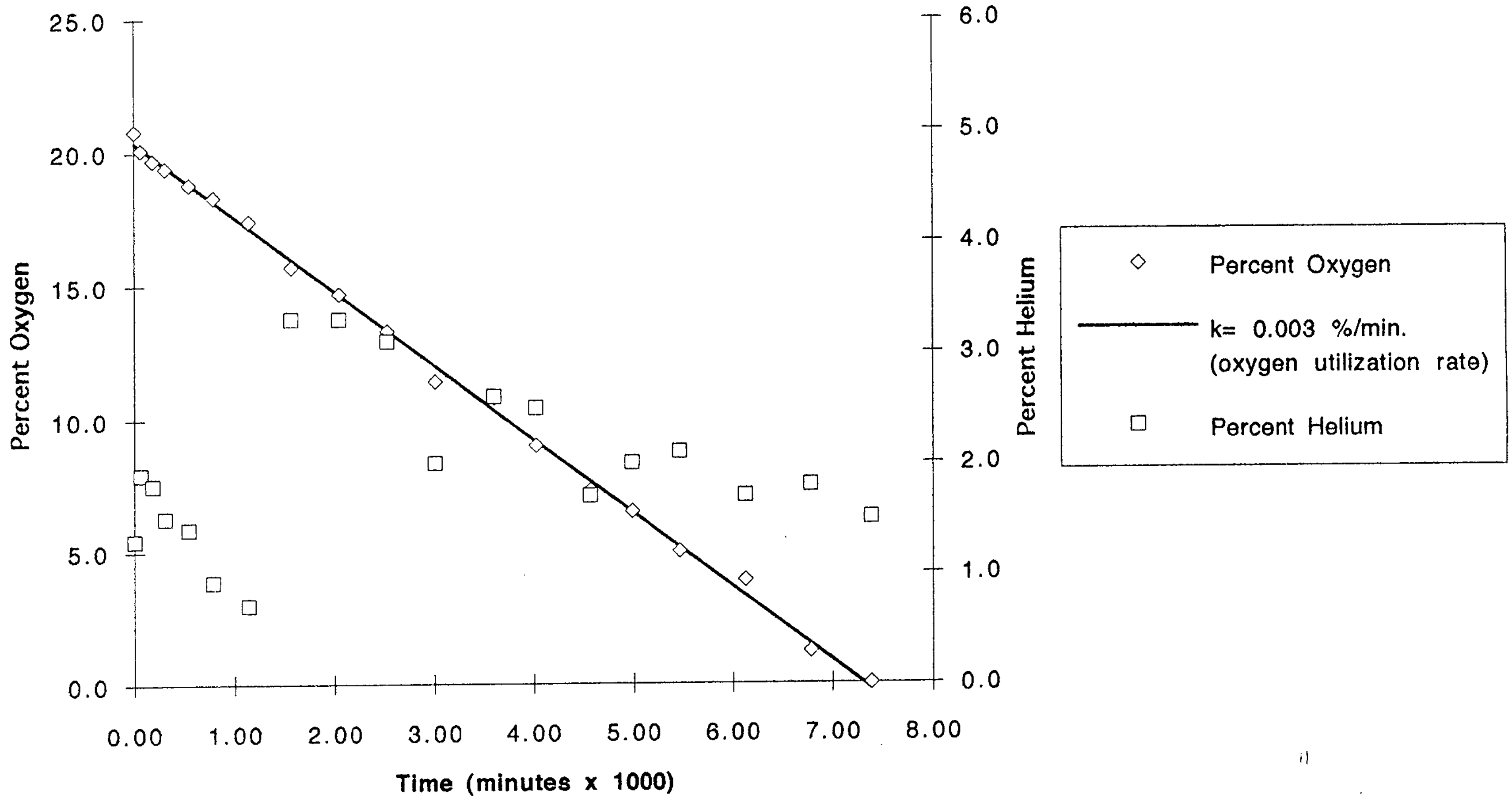


Figure 2.7

Respiration Test
Oxygen and Helium Concentrations
BX Service Station MPB
Patrick AFB, FL

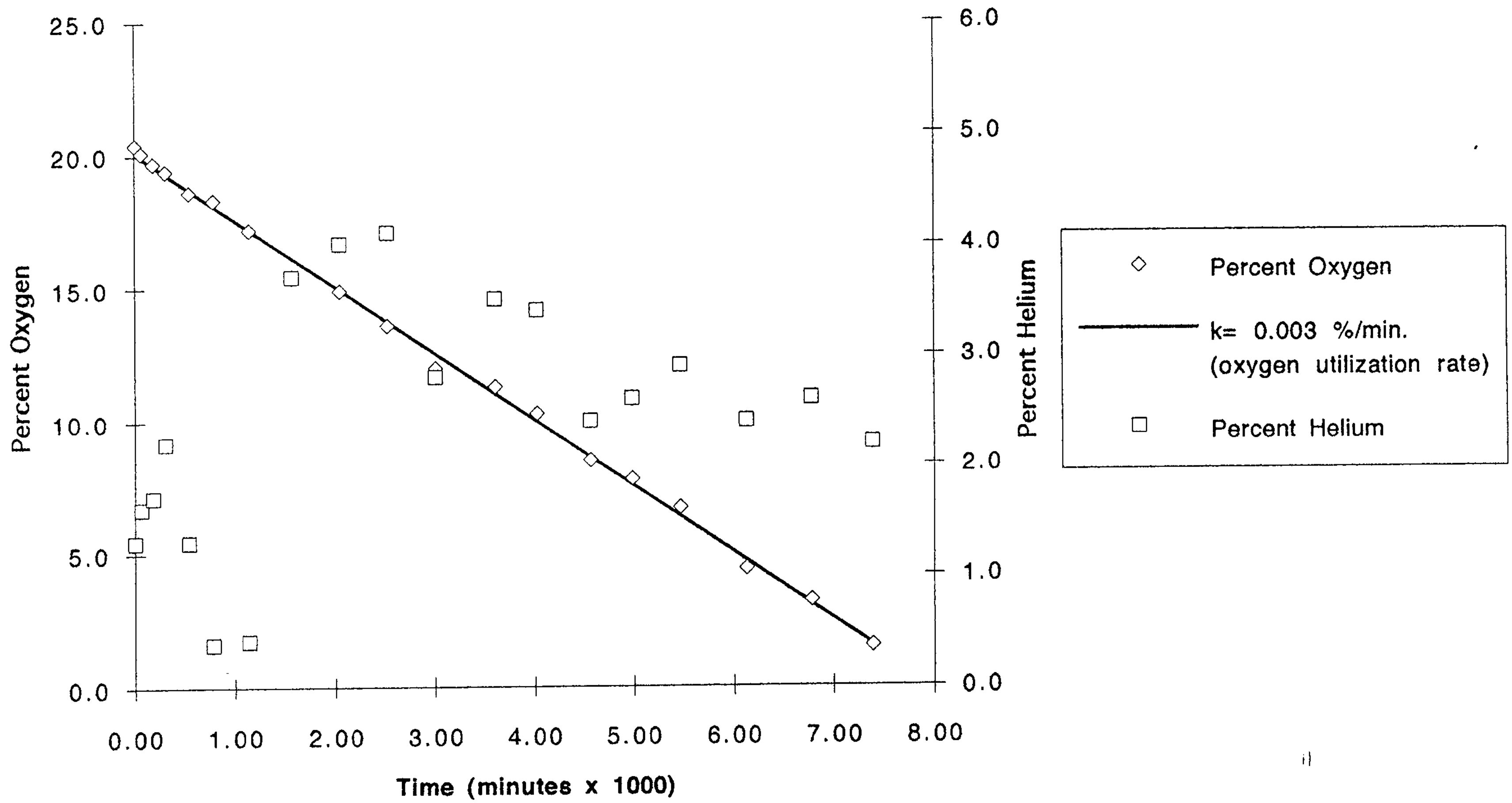


Figure 2.8

Respiration Test
Oxygen and Helium Concentrations
BX Service Station MPC
Patrick AFB, FL

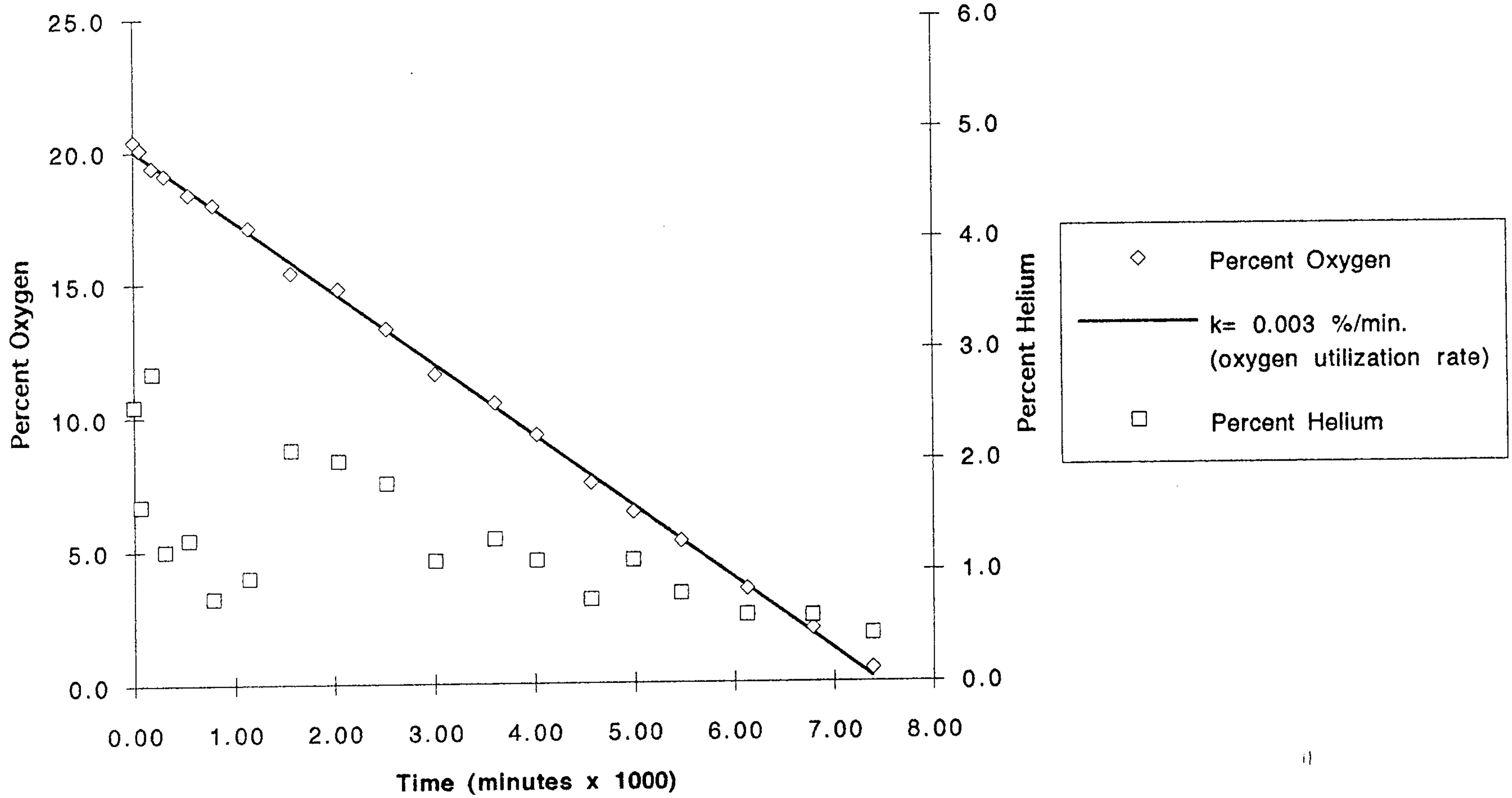


TABLE 2.5

OXYGEN UTILIZATION RATES

BX SERVICE STATION

PATRICK AFB, FLORIDA

Location	O_2 Loss[a/] (%)	Test[b/] Duration (min)	O_2 Utilization[c/] Rate (%/min)
MPA	20.8	7390	0.003
MPB	18.9	7390	0.003
MPC	19.4	7390	0.003

a/ Actual measured oxygen loss.

b/ Elapsed time from beginning of test to time when minimum oxygen concentration was measured.

c/ Values based on best-fit lines (Figures 2.6 through 2.8).

fuel per kilogram (kg) of soil can be degraded each year at this site. This estimate is based on an average air-filled porosity of approximately 0.17 liter per kg of soil, and a ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. Additional information on the calculation for fuel biodegradation can be found in Section 5 of the protocol. Actual rates will vary and could be reduced during the rainy season due to higher soil moisture and reduced air-filled porosity.

2.5.5 Potential For Air Emissions

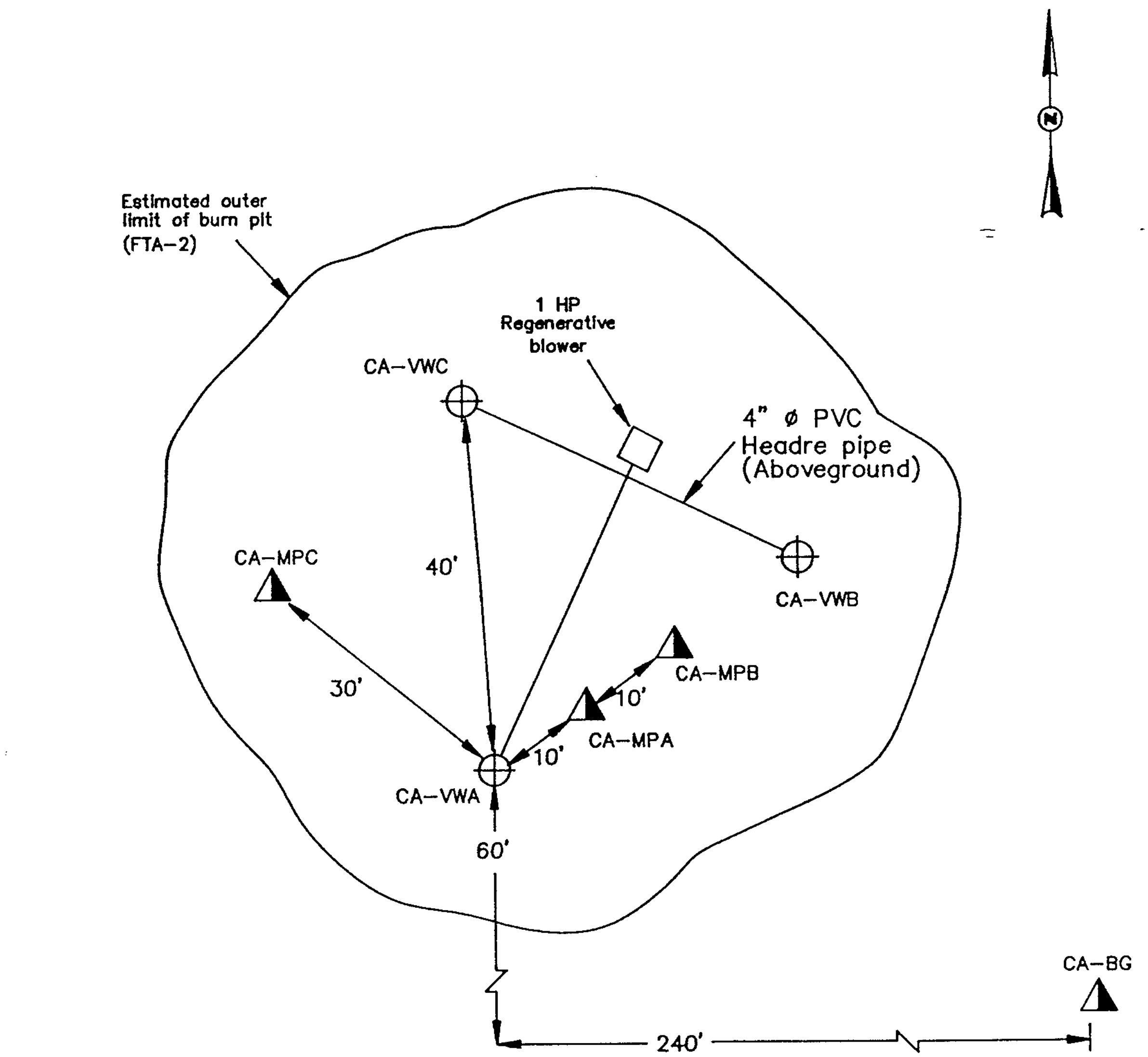
The long-term potential for air emissions from full-scale bioventing operations at this site is considered low because soil vapor extraction will be used to remove the initial high levels of BTEX from the soil and a vapor-phased carbon and an above ground biofilter system will be used to treat the off-gas. The treatment system will be sized based on a flow rate of 30 scfm and the initial average soil gas TVH level of 60,000 ppmv decreasing to 1000 ppmv during the first 60 days of treatment. The above ground biofilter will be used to remove the majority of the hydrocarbons with carbon cannisters used to polish the air discharge to the desired 99 percent removal. During the first 60 days, total volatile hydrocarbon samples will be collected from the treatment system inlet and outlet each week to insure 99 percent removal of fuel vapors. After approximately 60 days of vapor extraction, the blower will be reversed and the air injection rate reduced to approximately 10 scfm, this low rate of injection will be used to supply oxygen for continued biodegradation of the remaining fuel residuals.

3.0 SITE FTA-2, CAPE CANAVERAL AFS

3.1 Pilot Test Design and Construction

The following sections describe the final design and installation of the bioventing system at site FTA-2. Three air injection venting wells (VWs) were installed on March 26, 1993 by Engineering-Science, Inc. (ES) Orlando, Florida and a subcontractor, Groundwater Protection, Inc. (Drilling Division) of Orlando, Florida. Four permanent pressure/vapor monitoring points (MPs) were installed on March 26, 1993. The VW construction, MP installations, and soil sampling were directed by Mr. Steve Archabal, the ES site manager. The following sections describe in more detail the final design, installation, and testing of the bioventing system at this site.

Three VWs, four permanent MPs, and a blower unit in a weather-proof enclosure were installed at site FTA-2. The locations of the MPs and VWs followed the original work plan found in Part IB of this report. A multi-depth MP construction was used at the site. Monitoring depth screen intervals of 2.5 to 3.0 and 5.5 to 6.0 feet below land surface (bls) were installed at this site. Figure 3.1 depicts the test area



LEGEND

CA-VWA — Air injection venting well

CA-MPA — Permanent soil vapor/pressure monitoring point.

20' 10' 0 20'
Approximate Scale in Feet

AS-BUILT VENTING WELL,
VAPOR MONITORING POINTS,
AND BLOWER LOCATIONS
SITE FTA-2

CAPE CANAVERAL, FLORIDA

ENGINEERING–SCIENCE, INC.
Orlando, Florida

ES

CA1-3-1.DWG

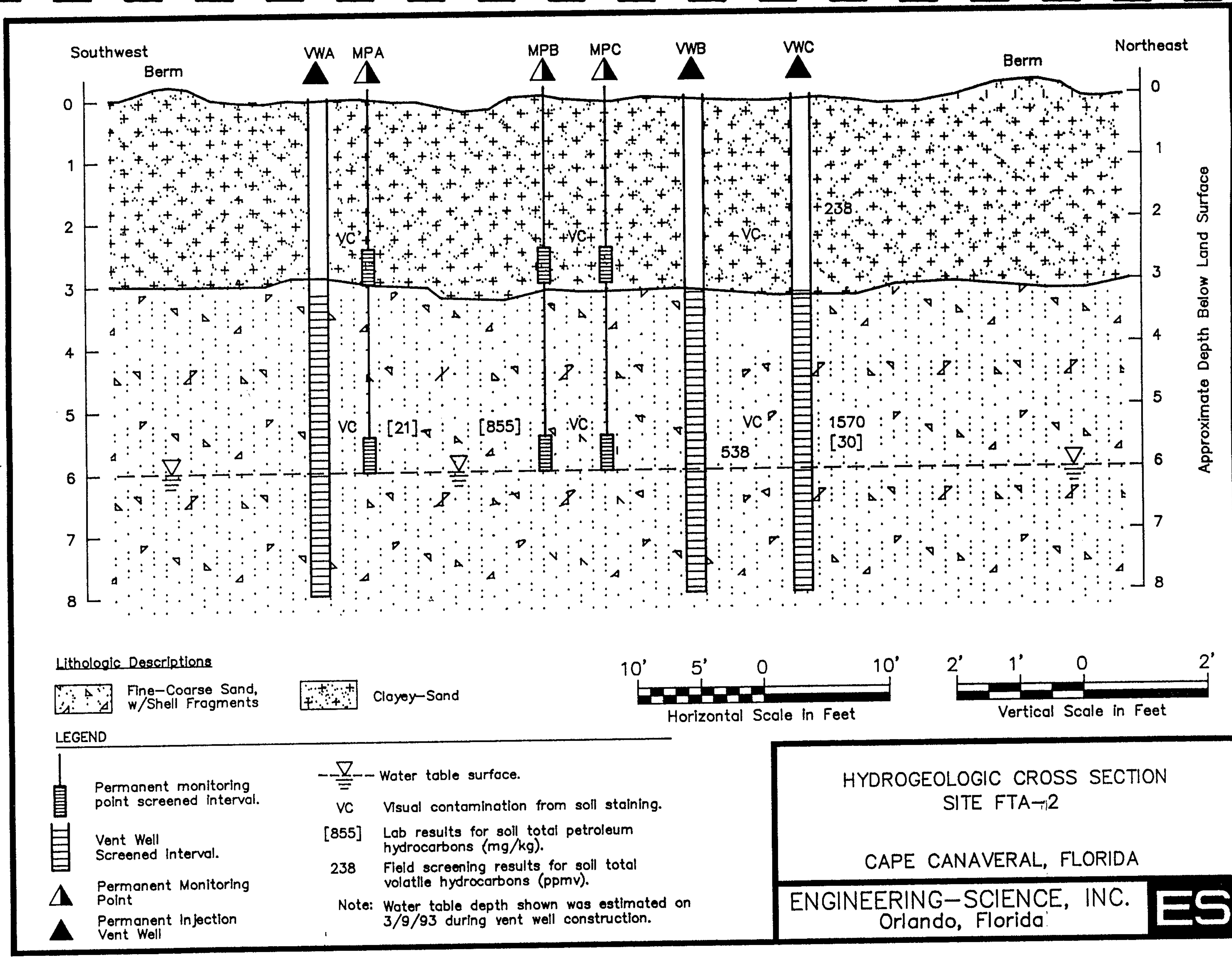


Figure 3.2

CA1–3–2.DWG

with the locations of the MPs, VWs, and blower at site FTA-2. Figure 3.2 shows a hydrogeologic cross section in a northeast-southwest direction.

3.1.1 Air Injection Venting Well Construction

The VWs were installed within the boundaries of the former firefighter training pit area, as shown in Figure 3.1. The VWs were constructed in visibly contaminated, oxygen-depleted soils. Soils encountered during the VW construction were darkly stained and emitted strong hydrocarbon odors.

The installation of the VWs were in accordance with typical AFCEE work plan protocols (Hinchee et al., 1992). On the date of the VW installations, water level at the FTA-2 site was approximately 6.0 feet bls. According to previous IRP reports for this site, water level elevations can vary between 6 and 10 feet bls. Consequently, the installation depth of the VWs were in accordance with the proposed depth in the bioventing pilot test work plan (see Part IB).

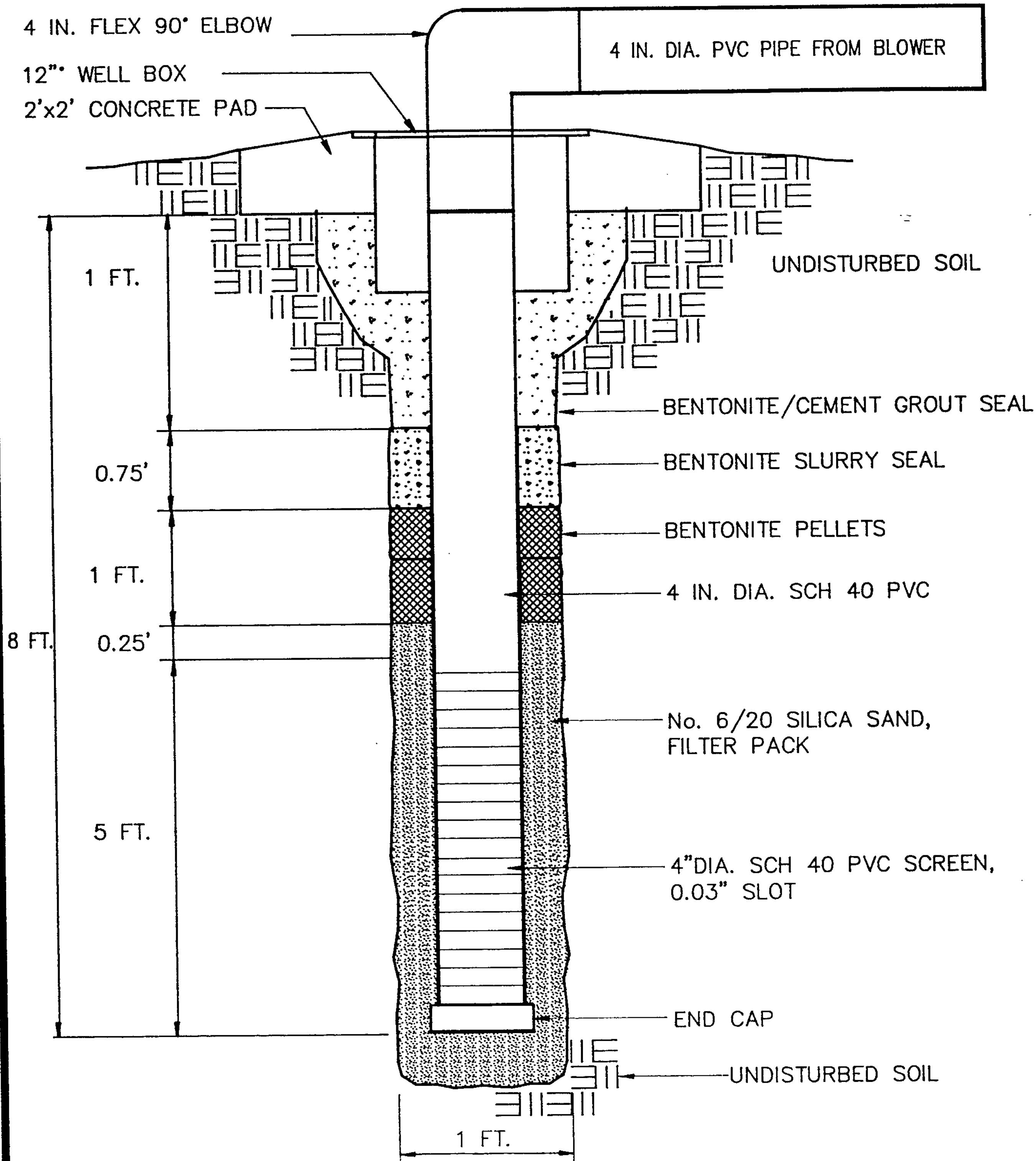
The VWs were constructed using 4-inch diameter, schedule 40 polyvinyl chloride (PVC) casing with 5 feet of 0.03-inch slotted PVC screen installed from 3 to 8 feet bls. The annular space between the well casing and borehole was filled with 6/20 graded silica sand to approximately 3 inches above the well screen. A 1-foot layer of bentonite pellets were placed above the sand, hydrated in place, followed by a 0.75 foot layer of bentonite slurry to complete the bentonite seal. A one foot cement grout seal was placed over the bentonite to ground surface. The top of each VW was completed with a flush-mount steel well manhole set in a 2x2-foot concrete pad. Figure 3.3 shows the as-built construction details for the VWs. The geologic soil boring log for the VW installations is in Appendix B.

3.1.2 Permanent Monitoring Points

Four permanent MPs were installed at site FTA-2 on March 26, 1993. Monitoring points CA-MPA, CA-MPB, CA-MPC were installed at respective distances of 10, 20, and 30 feet from the VWA location. A permanent background monitoring point, MPBG was installed 60 feet south and 240 feet due east of the VWA location (see Figure 3.1). All permanent MP boreholes were advanced using a decontaminated stainless steel hand auger. Monitoring points MPA, MPB, MPC were screened at two different depth intervals: 2.5-3.0 and 5.5-6.0 feet bls.

All four permanent MPs were constructed using 0.5-inch diameter PVC screens and casing installed in 4-inch diameter boreholes. Each MP was constructed using a 6-inch section of 0.02-inch slotted, schedule 40 PVC screen and schedule 80 PVC casing. The screened interval was surrounded by a filter pack of 6/20 graded coarse silica sand.

Figure 3.3



NOT TO SCALE

NOTE: AS-BUILT CONSTRUCTION DETAIL WAS THE SAME FOR ALL THREE VENT WELLS AT SITE FTA-2

AS-BUILT INJECTION VENT WELL CONSTRUCTION DETAIL
SITE FTA-2

CAPE CANAVERAL, FLORIDA

ENGINEERING-SCIENCE, INC.
Orlando, Florida

ES

CA1-3-3.DWG

Thermocouples were also installed at the screened interval of all the MPs. Bentonite pellets, hydrated in place were used to seal the annulus around each MP riser above the gravel pack and between the screened intervals. Then a 1-foot grout seal was placed over the bentonite to ground surface. The top of each MP PVC riser was completed at ground surface with a brass gas ball valve and a 1/4-inch brass hose barb and labeled using a metal I.D. tag. Each MP was completed at the surface with a 12-inch flush-mounted steel manhole set in a concrete 2x2-foot pad. The lid to the manhole was set approximately 3 inches above ground surface, and the concrete base was sloped toward the edges to promote drainage of surface water away from the MP. Figure 3.4 shows a typical permanent MP construction detail.

3.1.3 Blower Unit Installation and Operation

A 1-horsepower Gast[R] regenerative blower unit was installed at site FTA-2 for the initial and extended pilot tests. The Gast[R] blower was installed in a weatherproof enclosure and electrically wired for 120 volt, 30 amp power. A portable generator was used to conduct the air permeability and respiration tests. Cape Canaveral AFS electricians will complete permanent electrical hook up at this site for the extended 1-year test.

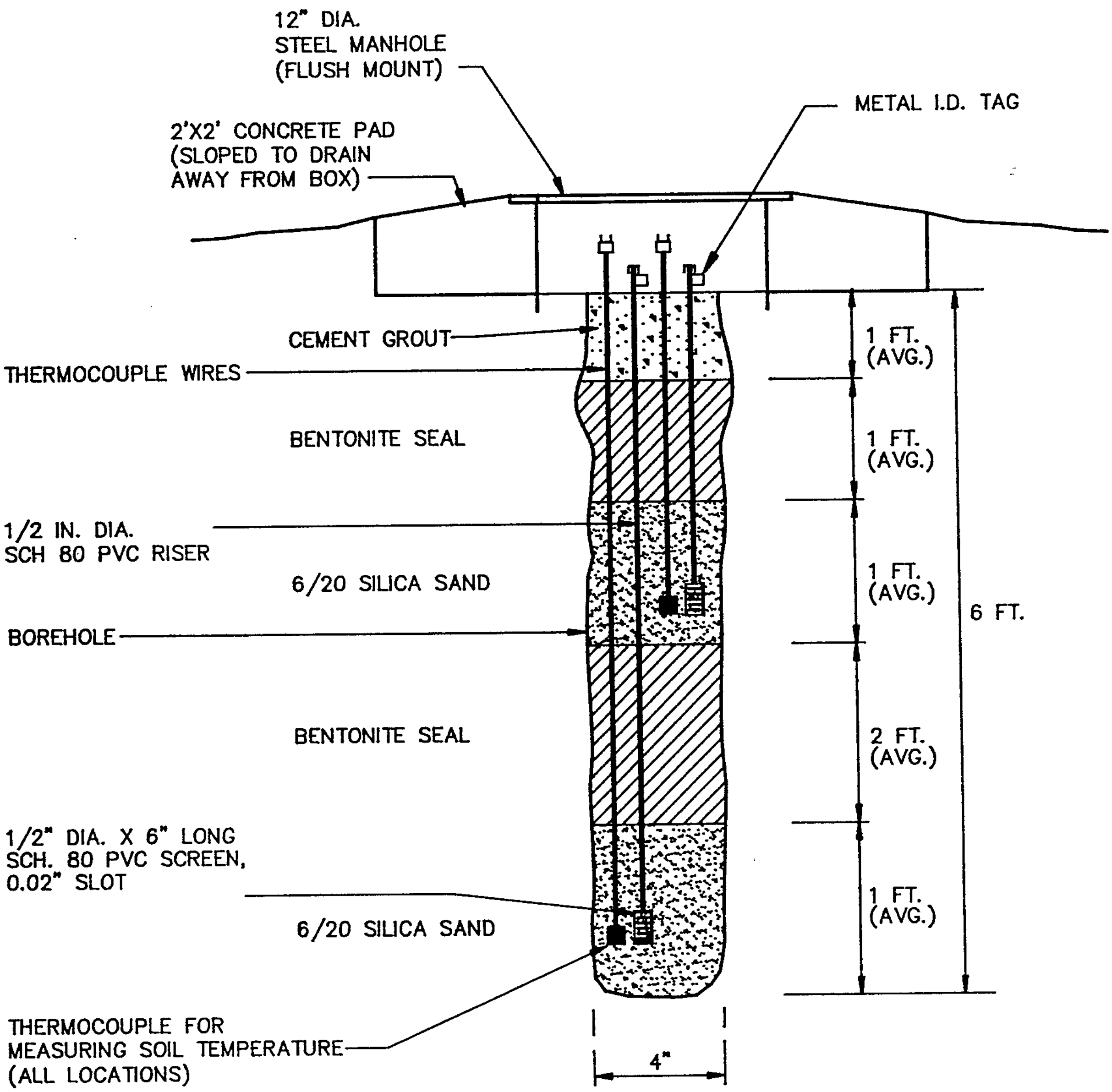
Air is supplied by the blower through a manifold to three 4-inch diameter above ground PVC header pipes that are attached to each of the VWs. Figure 3.5 shows the configuration, instrumentation, and specifications for the blower and air injection system.

Prior to departing from the site, ES personnel will provide operations and maintenance (O & M) instructions to base personnel. A copy of the O & M checklist is provided in Appendix A.

3.2 SOIL AND SOIL GAS SAMPLING RESULTS

Soils at site FTA-2 consist of loose, fine to medium grained sand, shells, shell fragments with minor amounts of clayey sand. This soil profile was consistent across the site at each boring location from ground surface to below the water table surface, which typically averages 6 to 10 feet bls. The fine to medium sands ranged in color from light gray to gray, with the exception being those areas that are stained dark gray from fuel contamination. The earthen berm, unlined fire training pit is overlain with light vegetation with some minor remnants of organic root material encountered in the upper one foot of the soil profile.

Soil hydrocarbon contamination at this site appears to be confined mainly within the bermed area. Contaminated soils were identified based on visual appearance,



MONITORING POINT CONSTRUCTION SPECIFICATIONS

Monitoring Point No.	Borehole Depth (FT)	Screen Interval (Feet BLS)
MPA–3.0 MPA–6.0	6	2.5–3.0 5.5–6.0
MPB–3.0 MPB–6.0	6	2.5–3.0 5.5–6.0
MPC–3.0 MPC–6.0	6	2.5–3.0 5.5–6.0
BACKGROUND MP–3.5	3.5	2.5–3.0

DRAWING IS NOT TO SCALE

AS–BUILT PERMANENT
MONITORING POINT CONSTRUCTION DETAIL
SITE FTA–2

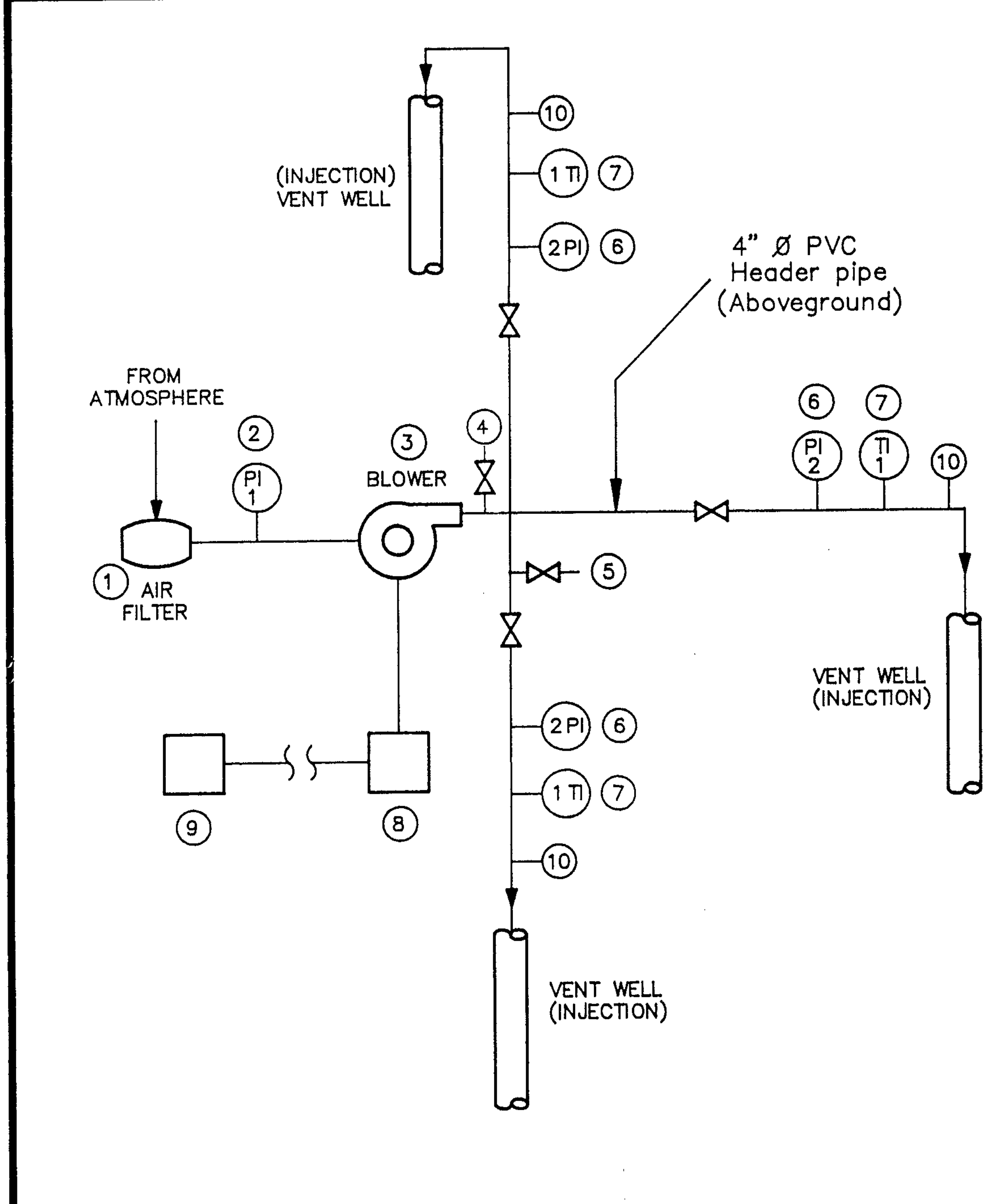
CAPE CANAVERAL, FLORIDA

ENGINEERING–SCIENCE, INC.
Orlando, Florida

ES

CA1–3–4.DWG

Figure 3.5



NOTES:

1. PERMANENT POWER WAS NOT INSTALLED AT THE TIME OF THE INTERIM PILOT TEST.

LEGEND

1. INLET AIR FILTER
2. VACUUM GAUGE (In H_2O)
3. BLOWER – GAST/70 SCFM @ 20 INCHES H_2O REGENERATIVE W/1HP DRIVE MOTOR
4. MANUAL PRESSURE RELIEF (BLEED) VALVE – 1 1/2" GATE
5. AUTOMATIC PRESSURE RELIEF VALVE
6. PRESSURE GAUGE (In H_2O)
7. TEMPERATURE GAUGE (°F)
8. POWER SWITCH
9. BREAKER BOX (115V/SINGLE PHASE/30 AMP)
10. AIR VELOCITY MEASURE PORT

DRAWING IS NOT TO SCALE

AS–BUILT BLOWER SYSTEM
FOR AIR INJECTION
SITE FTA–2

CAPE CANAVERAL, FLORIDA

ENGINEERING–SCIENCE, INC.
Orlando, Florida

ES

CA1–3–5.DWG

odor and volatile organic compound (VOC) field screening results. Heavily contaminated soils were encountered during the VW installations and during all MP installations; the only exception being the background MP location (MPBG). Soil contamination exhibited hydrocarbon odors and were visibly stained from dark oily fuel. Soil gas VOC readings exceeded 20,000 parts per million, volume per volume (PPMV) of total hydrocarbons in all the MPs and VW locations.

Soil samples for laboratory analysis were collected from the stainless steel hand auger bucket during the installation of the permanent MPs. Soil samples were collected from a depth of 5.5 feet at MPA and MPB locations; and from a depth of 6 feet at the CA-VWC location. Soil samples were screened for VOCs using a GasTech/Trace-techtor[R], hydrocarbon analyzer, to determine the presence of contamination and to select soil samples for laboratory analysis.

Soil samples were shipped via Federal Express to the ES Berkeley laboratory for chemical and physical analyses. Each of the soil samples were analyzed for the following parameters: total recoverable petroleum hydrocarbons (TRPH); benzene, toluene, ethylbenzene and xylenes (BTEX); iron; alkalinity; total Kjeldahl nitrogen (TKN); pH; phosphates; percent moisture; and grain size distribution. Soil gas samples were shipped via Federal Express to Air Toxics Inc. in Rancho Cordova, California for total volatile hydrocarbon (TVH) and BTEX analyses. The results of these analyses are presented in Table 3.1 and the chain-of-custody form is presented in Appendix C.

3.3 EXCEPTIONS TO TEST PROTOCOL DOCUMENT PROCEDURES

Test procedures described in the protocol document were used to complete treatability pilot tests at this site. There were two exceptions to the standard protocol document and the Bioventing Pilot Test Work Plan (Part IB) at site FTA-2. The bentonite seals in the MPs and VWs were hydrated in place instead of using a bentonite slurry mixture; and soil sampling procedures were also modified from the protocol because MP boreholes were installed with a hand auger. Samples obtained for laboratory analyses were collected directly from hand auger cuttings and were not obtained using brass sampling sleeves (liners) as stated in the protocol.

3.4 FIELD QA/QC RESULTS

Field quality assurance/quality control (QA/QC) samples were not collected or required at this site.

TABLE 3.1
SOIL AND SOIL GAS LABORATORY ANALYTICAL RESULTS
Site FTA-2
Cape Canaveral AFS, Florida

Analyte (Units)[a/]	Sample Location-Depth (feet below ground surface)		
Soil Gas Hydrocarbons	VWC	MPA - 6	MPB - 6
TPH (ppmv)	3,400	4,400	NS[d/]
Benzene (ppmv)	0.82	2.2	NS
Toluene (ppmv)	ND[b/]	ND	NS
Ethylbenzene (ppmv)	2.1	5.0	NS
Xylenes (ppmv)	4.5	5.1	NS
Soil Hydrocarbons	VWC - 6	MPA - 5.5	MPB - 5.5
TRPH (mg/kg)	30.03	21.89	855.4
Benzene (mg/kg)	ND	ND	ND
Toluene (mg/kg)	12	.00035	.65
Ethylbenzene (mg/kg)	7.2	.00034	.7
Xylenes (mg/kg)	15	.015	4.9
Soil Inorganics			
Iron (mg/kg)	2,390[c/]	157[c/]	41.9[c/]
Alkalinity (mg/kg as $CaCO_3$)	360	110	ND
pH (units)	7.4	7.8	7.9
TKN (mg/kg)	34	ND	ND
Phosphates (mg/kg)	570	130	130
Soil Physical Parameters			
Soil Temperature (°F)(3-ft/6-ft)	NS	74.5/70.9	NS/71.4
Moisture (% wt.)	24.2	14.5	4.3
Gravel (%)	0	0	0
Sand (%)	92	95	98
Silt (%)	5	2	1
Clay (%)	3	3	1

a/ TRPH = total recoverable petroleum hydrocarbons; TPH = total petroleum hydrocarbons; mg/kg = milligrams per kilogram, ppmv = parts per million, volume per volume; $CaCO_3$ = calcium carbonate; TKN = total Kjeldahl nitrogen.

b/ ND = not detected.

c/ Laboratory analytical results outside normal QC limits.

d/ NS = not sampled.

3.5 PILOT TEST RESULTS

3.5.1 Initial Soil Gas Chemistry

Prior to initiating any air injection, all MPs were purged until oxygen levels had stabilized, and initial oxygen, carbon dioxide, and TVH concentrations were sampled using portable gas analyzers, as described in the technical protocol document. At all MP screened intervals and at the HVW, microorganisms had completely depleted soil gas oxygen supplies, indicating significant biological activity and soil contamination. The uniformity of zero oxygen levels at this site is primarily the result of the vertical and horizontal uniformity of soil contamination. Table 3.2 describes initial soil gas chemistry at the site. A background MPBG located approximately 250 feet east from the center of the spill had near atmospheric levels of oxygen and carbon dioxide. This indicates that uncontaminated soils at the same depth do not exert significant oxygen demand due to natural organic biodegradation or abiotic reactions.

3.5.2 Air Permeability

An air permeability test was conducted according to protocol document procedures. Air was injected into the VWA for 20 minutes at a rate of approximately 45 scfm and an average pressure of 39 inches of water. Steady-state pressure levels were achieved in all MPs after approximately 20 minutes of air injection. Table 3.3 provides the steady-state pressures at each MP. Due to this rapid pressure response, the steady-state method of determining air permeability was selected. A soil gas permeability value of 21 darcy was calculated for this site. A radius of pressure influence of over 30 feet was observed at this flow rate. The flow was then split between all three VWs and approximately 25 scfm was injected into VWA. At this reduced flow rate, the radius of pressure influence still exceeded 30 feet. Based on this test, it appears that less that 20 scfm per well will be adequate for providing oxygen to the entire fire training area.

3.5.3 Oxygen Influence

The radius of oxygen increase in the subsurface resulting from air injection into VWA is the primary design parameter for full-scale bioventing at this site. Table 3.4 presents the change in soil gas oxygen levels that occurred during one hour of air injection. This period of air injection at approximately 45 scfm produced changes in soil gas oxygen levels at a distance of at least 20 feet from the VW. Based on the pressure influence of at least 30 feet, the long-term radius of oxygen influence should also exceed 30 feet. During the start up of the extended pilot test, the air injection rate will be reduced to the minimum flow required to provide oxygen to

TABLE 3.2
INITIAL SOIL GAS CHEMISTRY
Site FTA-2
Cape Canaveral AFS, Florida

Sample Location	Depth (ft)	O_2(%)[d]	CO_2(%)[d]	FIELD TVH (ppmv)[a]	LAB TVH (ppmv)[b]	LAB TPH (mg/kg)[b]
MPA	3	0.0	11.1	>20,000	NS	NS[c]
MPB	3	0.0	10.5	>20,000	NS	NS
MPC	3	0.0	12.9	>20,000	NS	NS
MPA	6	0.0	14	>20,000	4,400[e]	21.98
MPB	6	0.0	14.2	>20,000	NS	855.4
MPC	6	0.0	16	>20,000	NS	NS
VWC	3.8	0.0	11.3	>20,000	3,400	30.03
Background	3	18	2.5	72	NS	NS

[a] Gastech/Trace-techtor field screening results.
[b] Laboratory results.
[c] NS = not sampled.
[d] Percentage based on mass of gaseous phase in vent stream.
[e] Field Duplicates both 4,400 ppmv.

TABLE 3.3

MAXIMUM PRESSURE RESPONSE

AIR PERMEABILITY TEST

FTA-2

CAPE CANAVERAL, FLORIDA

	Distance from injection well (VWA) (feet)					
	10 (MPA)		20 (MPB)		30 (MPC)	
Depth (feet)	3	6	3	14	3	6
Time (min)	20	20	20	20	20	20
Max Press. (inches H_2O)	7.0	12.3	3.2	6.7	3.2	6.4

TABLE 3.4
INFLUENCE OF AIR INJECTION AT VENT WELL ON MONITORING POINT OXYGEN LEVELS
FTA-2
CAPE CANAVERAL, FLORIDA

MP	Distance From VW (ft)	Depth(ft)	Initial O_2(%)	Final O_2(%) Permeability Test[a/]
A	10	3	0.0	9.8
B	20	3	0.0	0.0
C	30	3	0.0	0.0
A	10	6	0.0	19.6
B	20	6	0.0	17.0
C	30	6	0.0	0.0

a/ Reading taken at end of 40 minutes air permeability test.

soils within a 30 feet radius of each VW. This should insure oxygenation of the entire contaminated soil volume beneath the former fire training area.

3.5.4 In Situ Respiration Rates

The *in situ* respiration test was performed by injecting a mixture of air (oxygen) and approximately 3 percent helium (inert tracer gas) into the deep interval of each MP for a 20-hour period. Oxygen loss and other changes in soil gas composition over time were then measured at each MP. Oxygen, TVH, carbon dioxide, and helium were measured for a period of approximately 120 hours following air injection. The measured oxygen losses were then used to calculate biological oxygen utilization rates. The results of *in situ* respiration testing for MPA-6, MPB-6, and MPC-6 are presented in Figures 3.6 through 3.8. Table 3.5 provides a summary of the oxygen utilization rates.

Figures 3.6 through 3.8 compare oxygen utilization and helium retention. Oxygen loss occurred at moderate rates, ranging from 0.002 percent per minute at MPA-6 to .004 percent per minute at MPC-6. Based on these oxygen utilization rates, an estimated 210 to 1350 milligrams (mg) of fuel per kilogram (kg) of soil can be degraded each year at this site. This estimate is based on air-filled porosities ranging from 0.05 to 0.16 liter per kg of soil, and a ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. Actual rates will vary and could be reduced during the rainy season due to higher soil moisture and reduced air-filled porosity.

3.5.5 Potential Air Emissions

The long-term potential for air emissions from full-scale bioventing operations at this site is considered low because of the low injection rate proposed for extended testing (<20 scfm/well) and the fact that initial soil gas BTEX levels were less than 15 ppmv. Health and safety monitoring was conducted during the one hour air permeability tests using a GasTech[R] Hydrocarbon Analyzer sensitive to 1 ppm increases in volatile hydrocarbons. No emissions in excess of 1 ppm were detected in the breathing zone during the one hour air permeability test. Because the potential for air emissions is highest during this initial hour of air injection, the long-term emission potential is considered low. The site is very isolated and several hundred feet from any occupied building.

4.0 RECOMMENDATIONS

Initial bioventing tests at these sites indicate that oxygen has been depleted in the contaminated soils, and that air injection is an effective method of increasing aerobic fuel biodegradation. AFCEE has recommended that air injection begin at

Figure 3.6

Respiration Test
Oxygen and Helium Concentrations
FTA-2 MPA
Cape Canaveral, FL

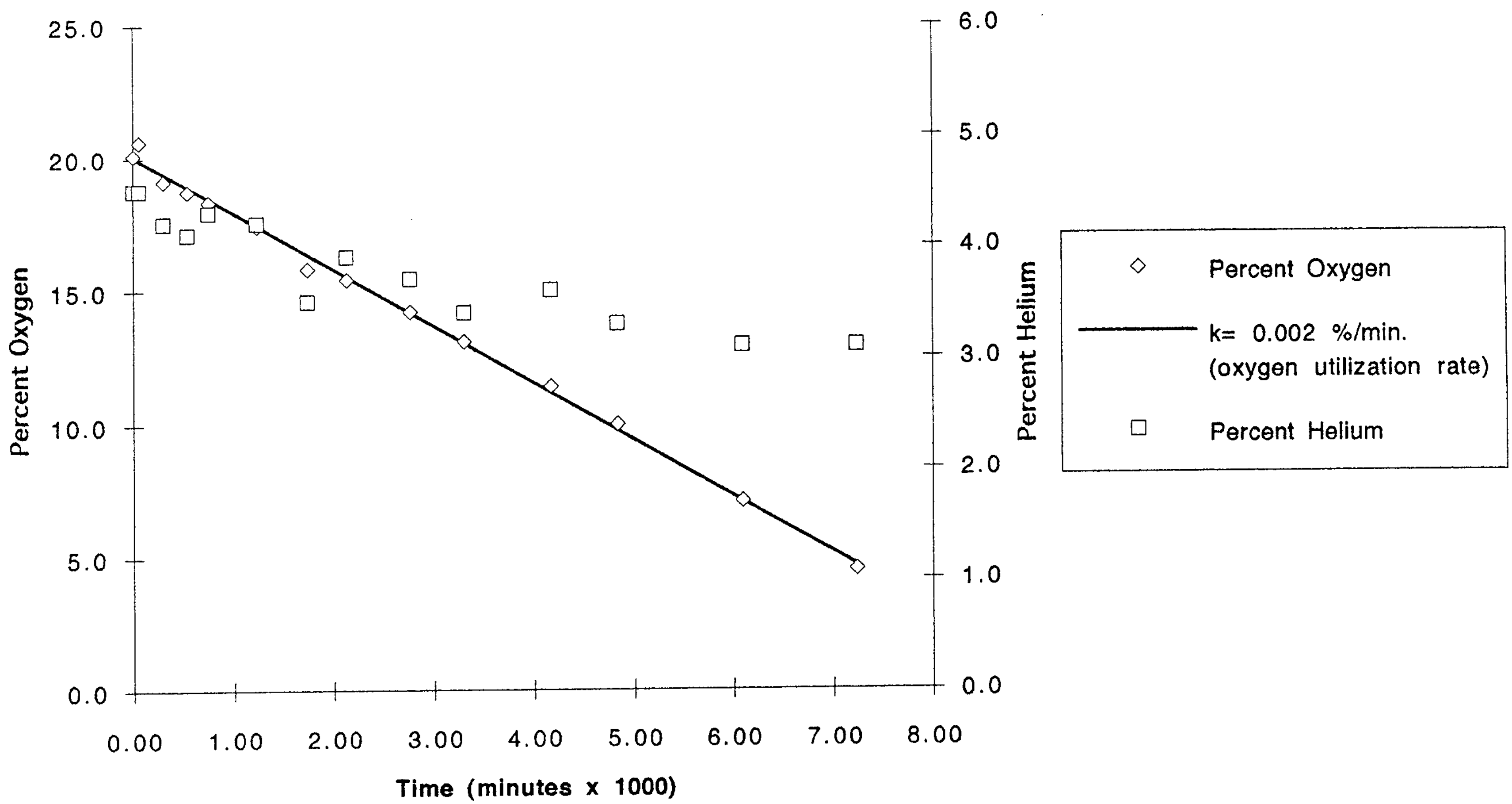


Figure 3.7

Respiration Test
Oxygen and Helium Concentrations
FTA-2 MPB
Cape Canaveral, FL

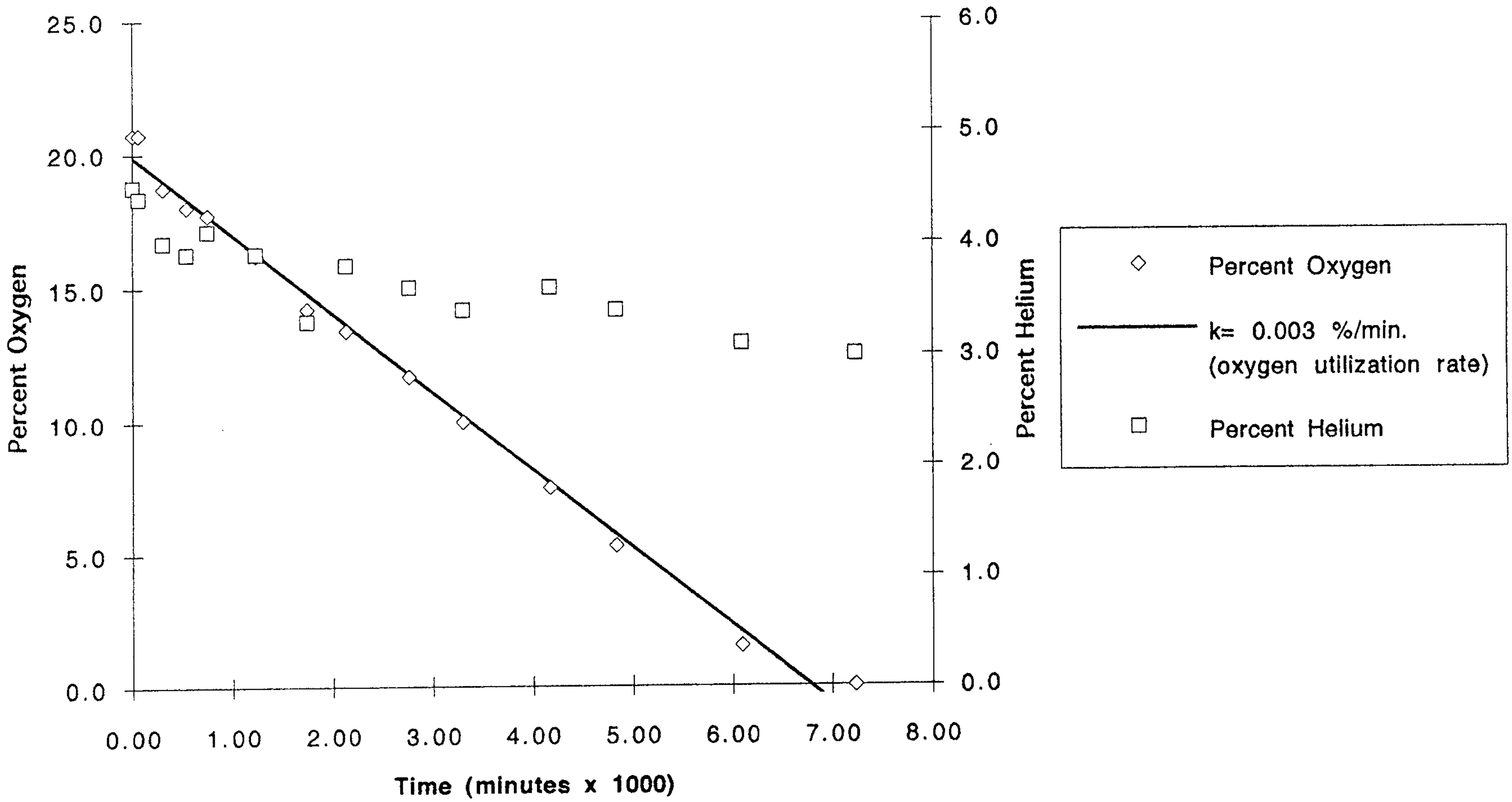


Figure 3.8

Respiration Test
Oxygen and Helium Concentrations
FTA-2 MPC
Cape Canaveral, FL

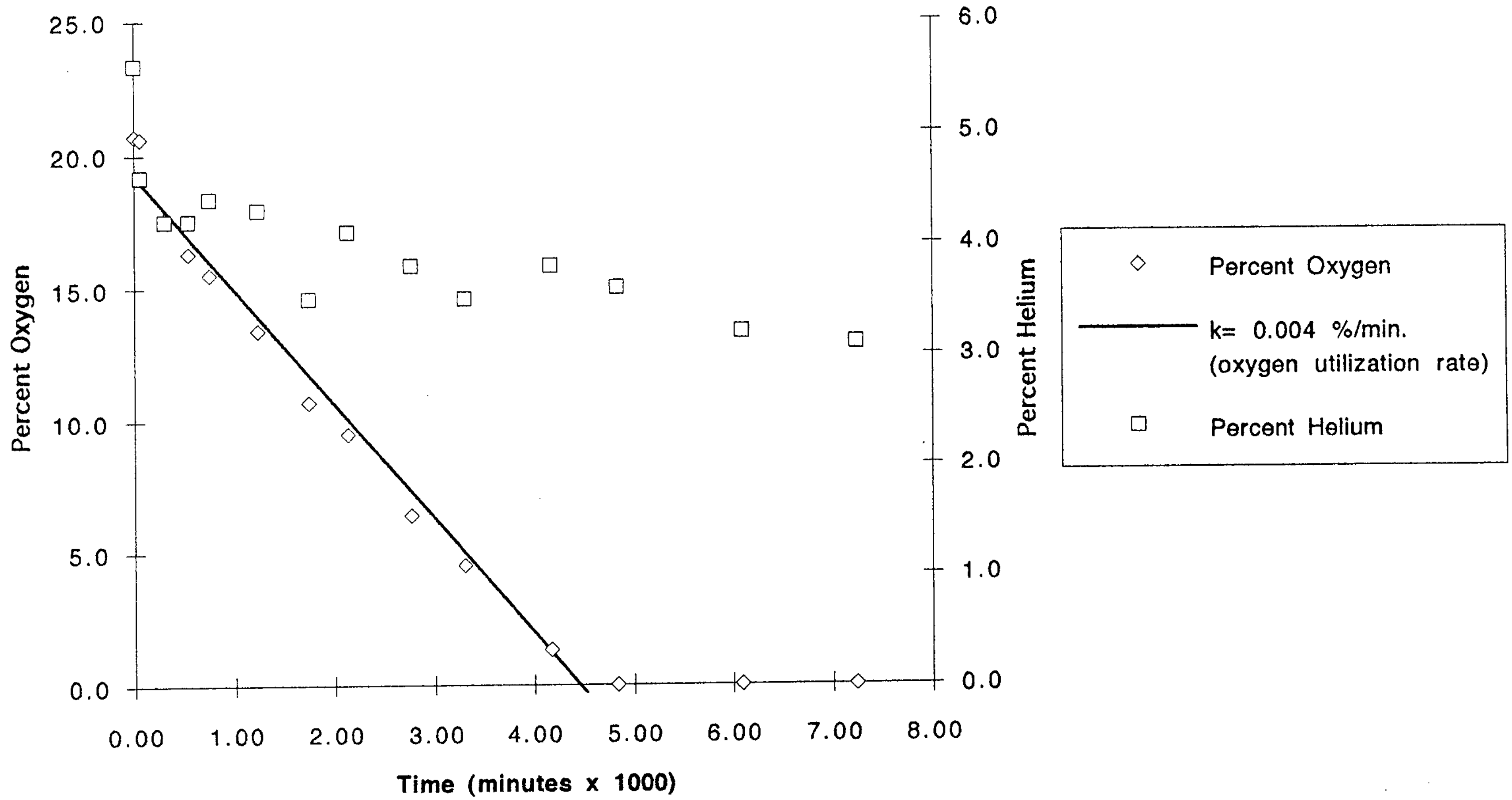


TABLE 3.5
OXYGEN UTILIZATION RATES
FTA-2
CAPE CANAVERAL, FLORIDA

Location	O_2 Loss[a/] (%)	Test[b/] Duration (min)	O_2 Utilization[c/] Rate (%/min)
MPA-6	15.6	7230	0.002
MPB-6	20.7	7230	0.003
MPC-6	20.7	4830	0.004

a/ Actual measured oxygen loss.
b/ Elapsed time from beginning of test to time when minimum oxygen concentration was measured.
c/ Values based on best-fit lines (Figures 3.6 through 3.8).

the two fire training areas on Patrick AFB and Cape Canaveral AFS to determine the long-term radius of oxygen influence and the effect of time, available nutrients, and changing temperatures on fuel biodegradation rates.

Small, 1-horsepower regenerative blowers have been installed at the two FTAs to continue air injection at a rate of approximately 10-20 scfm per well. A 1-horsepower explosion-proof blower has be installed at the Patrick AFB Service Station and will be initially operated in a vapor extraction mode and later in an air injection mode as described in Section 2.5.5. Following regulatory approval to proceed, and construction of a permanent power supply, the extended one year pilot test will begin at each site. Six months after the extended test begins, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test. A final respiration test will be conducted, and soil and soil gas samples will be collected from the site to determine the degree of remediation achieved during the first year of *in situ* treatment.

Based on the results of the first year of pilot-scale bioventing, AFCEE will recommend one of three options:

1. Upgrade, if necessary, and continue operation of the bioventing system for full-scale remediation of the site.
2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved.
3. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE may recommend removal of the blower system and proper abandonment of the VW and MPs.

5.0 REFERENCES

Hinchee, R.E., S.K. Ong., R.N. Miller, D.C. Downey, and R. Frandt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* Prepared for USAF Center for Environmental Excellence. May.

APPENDIX A

SYSTEM MAINTENANCE

APPENDIX A

SYSTEM MAINTENANCE

A.1 BLOWER/MOTOR MAINTENANCE

The blower and motor are relatively maintenance free. There is no lubrication required because the blower and motor have sealed bearings. If a blower system is in need of repair, please contact Steve Archabal at (407) 841-8114.

A.2 FILTER MAINTENANCE

To avoid damage caused by passing solids through the blower, an air filter has been installed inline before the blower. By design, Gast^{R} regenerative blowers are able to ingest small quantities of particles without damage. However, continuous ingestion of solids will damage or imbalance the impellers. The inline air filter will prevent solids from entering the blower, and is rated at 99 percent efficiency to 10 microns.

The filter element is a polyester cloth and can be cleaned and reused, or replaced. The filter should be checked weekly for the first two months of operation. The air filter should be cleaned or replaced when the pressure difference across the filter reaches 15 to 20 inches of water. It is the responsibility of Patrick AFB and Cape Canaveral AFS to determine the best schedule for filter cleaning and/or replacement, depending on the results of the initial observations.

The filter can be checked after turning off the blower system. To remove the filter, loosen the clamps, lift the metal top off the air filter, and lift the air filter from the metal housing. When replacing the filter, be careful that the rubber seals remain in place. The filter is manufactured by Solberg Manufacturing, Inc. in Itasca, Illinois. Their phone number is (708) 773-1363. The filters can also be obtained through Fluid Technology, Inc. in Denver, Colorado. The contacts there are Mr. Bob Cook and Mr. Greg Sparks; they can be reached at (303) 233-7400. It is recommended that Patrick AFB keep at least three spare air filters; one for each site.

A.3 BLOWER PERFORMANCE MONITORING

To monitor the blower performance, vacuum, pressure, and temperature will be measured. These data will be recorded on the data collection sheets provided. All measurements will be taken at the same time while the system is running.

A.3.1 Pressure/vacuum

Record the pressure and vacuum readings directly from the gauges in inches of water. Record the measurements on the data collection sheet provided.

A.3.2 Temperature

Record the temperature readings directly from the gauges in degrees Fahrenheit. Record the measurements on the data collection sheet provided.

A.3.3 Offgas Monitoring

On the extraction system proposed at the BX Service Station site, Patrick AFB; during the initial two months of operation as vapor extraction, offgas sampling will be conducted in order to monitor the off-gas constituents. A sampling port will be placed in the exhaust piping for sample collection.

ES will conduct initial sampling during first 8 weeks of operation.

A.4 MONITORING SCHEDULE

The following monitoring schedule is recommended for this system. During the initial months of operation, more frequent monitoring is recommended to ensure that any start up problems are quickly corrected. Data collection sheets have been provided to record the system data.

Site	Monitoring Item	Monitoring Frequency
FTA-2 Patrick AFB & FTA-2 Cape Canaveral AFS	Blower vacuum/ pressure and temperature	Weekly
BX Service Station Patrick AFB	Offgas Sampling	Weekly for the first 2 months of operation, or as dictated by the State regulatory air permit department.
	Blower vacuum/ pressure and temperature	Weekly

BLOWER INJECTION SYSTEM DATA COLLECTION SHEET

SITE:________

DATE	TIME	INLET VACUUM (IN. WATER)	OUTLET TEMP. (DEGREES F)	OUTLET PRESSURE (IN. WATER)	FILTER CHANGED (Y or N)	BLOWER FUNCTIONING UPON ARRIVAL (Y or N)	COMMENTS	CHECKED BY

APPENDIX B

GEOLOGIC BORING LOGS

GEOLOGIC BORING LOG

BORING NO.	CA-VWA CA-VWB, CA-VWC	CONTRACTOR:	GROUNDWATER PROTECTION	DATE SPUD:	3/26/93
CLIENT:	AFCEE	RIG TYPE:	AUGER	DATE CMPL:	3/26/93
JOB NO.:	DE268.26	DRLG METHOD:	HSA	ELEVATION:	+6' FT-MSL
LOCATION:	CAPE CANAVERAL AFS	BORING DIA.:	12"	TEMP.:	75° F
GEOLOGIST:	SRA	DRLG FLUID	NONE	WEATHER:	CLOUDY

COMMENTS: Geologic descriptions at this site were the same for all boring locations

Elev. (ft.)	Depth (ft.)	Profile	USCS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1		SC	Clayey-sand, Lt-dk gray, w/sm shell fragments, strong fuel odor	VWC	0-2	G		TVH=238 (2')
	5		SP-SC	Sand, F-C, Lt-dk gray stain, moist, sm shell fragments, with lenses of clayey-sand, strong fuel odor		2-6	G		TVH=1,570 (6') @ 6'
									TD=8.0'
	10								
	15								
	20								
	25								
	30								

sl – slight	v – very	f – fine	**SAMPLE TYPE**
tr – trace	lt – light	m – medium	D – DRIVE
sm – some	dk – dark	c – coarse	C – CORE
& – and	bf – buff	BH – Bore Hole	G – GRAB
@ – at	brn – brown	SAA – Same As Above	
w – with	blk – black		

C Core recovery

Core lost

Water level drilled

APPENDIX C

CHAIN OF CUSTODY FORMS

CHAIN OF CUSTODY RECORD

ENGINEERING-SCIENCE, INC.
1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

AFCEE BIOVENTING PILOT TESTS

Base: PATRICK AFB, FL

Site: BX STATION (PA-1)

ES Job No. DE268.27.08

Preservative: NONE

Ship To:
AIR TOXICS LTD.
11325 Sunrise Gold Circle, Suite E
Rancho Cordova, CA 95742

Attn: Bob Freeman
(916) 638-9892

Sampler(s): (Signature) Steven R. Ruchabal

	Date	Time	Sample Description	Lab I.D.	No. of Contrs.	TO-3(EPA)	(BTEX & TPH)	Sample Type	Matrix	Remarks
01A	4/16/93	1351	PA1-HVW		1	X	X	G C	AIR	2" H₂O
02A	4/16/93	1400	PA1-MPA-3.5		1	X	X	G C	AIR	1.5" H₂O
03A	4/16/93	1410	PA1-MPC-3.5		1	X	X	G C	AIR	1.5" H₂O
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	

Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time
Steven R. Ruchabal	4/16/93 1830	[illegible] A.T.L.	4/17/93 09:10
Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time

Remarks:

G - Grab Sample, C - Composite Sample

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files
Federal Express Number: ____
Airbill Number: ____

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900 • Denver, Colorado
(303) 831-8100

CCRAIR

CHAIN OF CUSTODY RECORD

Page 1 of 1

ENGINEERING-SCIENCE, INC.
1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

ES Job No.
DE268. 2 7 .08

AFCEE BIOVENTING PILOT TESTS

Base: PATRICK AFB, FL

Site: BX SERVICE STATION

Sampler(s) (Signature) Steven R. Archabal

Preservative: NONE | HOLD AT 4C | NONE

Analysis Required

Ship To:
ENGINEERING-SCIENCE LABORATORY
600 Bancroft Way
Berkeley, CA 94710

Attn: Tom Paulson
(510) 841-7353

Date	Time	Sample Description	Lab I.D.	No. of Contrs.	SW 9045 (PH)	A 403 (ALKA)	SW 7380 (IRON)	SW 846 (MOIST)	SW 8020 (BTEX)	E 418.1 (TRPH)	E 351.2 (TKN)	E 365.3 (PHOS)	UCM (CLASS)	Sample Type	Matrix	Remarks
03/09/93	1200	PA1-HVW-4.5		3		/				/		/		G C	SOIL	
03/09/93	1530	PA1-MPA-3.5		3		/				/		/		G C	SOIL	
03/09/93	1540	PA1-MPC-3.5		3		/				/		/		G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
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														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	

Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time	Remarks:
Steven R. Archabal TO FED EX	03/10/93 1500	[signature]	03/11/93 0830	TEMP. 4°C
Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time	G - Grab Sample, C - Composite Sample

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files
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(303) 831-8100

CCRSOIL

CHAIN OF CUSTODY RECORD

ENGINEERING-SCIENCE, INC.
1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

ES Job No. DE268. 27 .08

AFCEE BIOVENTING PILOT TESTS

Base: PATRICK AFB, FL

Site: FTA-2 (PA-2)

Preservative: NONE

Ship To:

AIR TOXICS LTD.
11325 Sunrise Gold Circle, Suite 4E
Rancho Cordova, CA 95742

Attn: Bob Freeman
(916) 638-9892

Sampler(s): (Signature) Steven R. Archabal

	Date	Time	Sample Description	Lab I.D.	No. of Contrs.	TO-3(EPA)	(BTEX & TPH)	Sample Type	Matrix	Remarks
4A	4/16/93	1500	PA2-HVW		1	X	X	G C	AIR	2" Hg
5A	4/16/93	1510	PA2-MPA-3.5		1	X	X	G C	AIR	2" Hg
6A	4/16/93	1520	PA2-MPD-3.5		1	X	X	G C	AIR	1.5" Hg
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	
								G C	AIR	

Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time
Steven R. Archabal	4/16/93 1830	[signature] A.T.L.	4/19/93 0940
Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time

Remarks:

G - Grab Sample, C - Composite Sample

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files

Federal Express Number:

Airbill Number:

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900 • Denver, Colorado
(303) 831-8100

CCRAIR

CHAIN OF CUSTODY RECORD

ENGINEERING-SCIENCE, INC.
1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

AFCEE BIOVENTING PILOT TESTS

Base: PATRICK AFB, FL

Site: FTA-2

ES Job No. DE268. 2 7 .08

Sampler(s): (Signature) Steven R. Archabal

Ship To:
ENGINEERING-SCIENCE LABORATORY
600 Bancroft Way
Berkeley, CA 94710

Attn: Tom Paulson
(510) 841-7353

Preservative: NONE (SW 9045, A 403, SW 7380, SW 846); HOLD AT 4C (SW 8020, E 418.1); NONE (E 351.2, E 365.3, UCM)

Analysis Required

Date	Time	Sample Description	Lab I.D.	No. of Contrs.	SW 9045 (PH)	A 403 (ALKA)	SW 7380 (IRON)	SW 846 (MOIST)	SW 8020 (BTEX)	E 418.1 (TRPH)	E 351.2 (TKN)	E 365.3 (PHOS)	UCM (CLASS)	Sample Type	Matrix	Remarks
03/11/93	0855	PA2-HVW-4		3		/			/			/		G C	SOIL	
03/11/93	1000	PA2-MPA-3.5		3		/			/			/		G C	SOIL	
03/11/93	1030	PA2-MPD-3.5		3		/			/			/		G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
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														G C	SOIL	
														G C	SOIL	
														G C	SOIL	

Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time	Remarks:
Steven R. Archabal TO FED EX	03/12/93	[signature]	3/13/93 1000	TEMP. 4°C
Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time	G - Grab Sample, C - Composite Sample

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files

Federal Express Number: ____

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1700 Broadway, Suite 900 • Denver, Colorado
(303) 831-8100

CCRSOIL

CHAIN OF CUSTODY RECORD

ENGINEERING-SCIENCE, INC.
1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

ES Job No. DE268. 2 6 .08

AFCEE BIOVENTING PILOT TESTS

Base: CAPE CANAVERAL AFS, FL

Site: FTA-2

Preservative: NONE

Sampler(s): (Signature) Steven R. Archabal

Ship To:
AIR TOXICS LTD.
11325 Sunrise Gold Circle, Suite E
Rancho Cordova, CA 95742

Attn: Bob Freeman
(916) 638-9892

Date	Time	Sample Description	Lab I.D.	No. of Contrs.	TO-3(EPA)	(BTEX & TPH)	Sample Type	Matrix	Remarks
4/16/93	1038	CA-VWC		1	X	X	G C	AIR	1" Hg
4/16/93	1100	CA-MPA-6		1	X	X	G C	AIR	1" Hg
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	

Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time
Steven R. Archabal	4/16/93 1830	[signature] A.T.C.	4/19/93 0910
Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time

Remarks: PLEASE RETURN COOLER TO: ENGINEERING-SCIENCE 255 S. ORANGE AVE., SUITE 1201 ORLANDO, FL 32801 PH# 407-~~841~~-8114

G - Grab Sample, C - Composite Sample

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files

Federal Express Number: ______

Airbill Number: ______

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900 • Denver, Colorado
(303) 831-8100

CHAIN OF CUSTODY RECORD

ENGINEERING-SCIENCE, INC.
1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

ES Job No. DE268. 2 6 .08

AFCEE BIOVENTING PILOT TESTS

Base: CAPE CANAVERAL, AFS
CAPE CANAVERAL, FL

Site: FTA-2

Sampler(s): (Signature) Steven R. Archabal

Ship To:
ENGINEERING-SCIENCE LABORATORY
600 Bancroft Way
Berkeley, CA 94710

Attn: Tom Paulson
(510) 841-7353

Date	Time	Sample Description	Lab I.D.	No. of Contrs.	SW 9045 (PH)	A 403 (ALKA)	SW 7380 (IRON)	SW 846 (MOIST)	SW 8020 (BTEX)	E 418.1 (TRPH)	E 351.2 (TKN)	E 365.3 (PHOS)	UCM (CLASS)	Sample Type	Matrix	Remarks
					Preservative: NONE	NONE	NONE	NONE	HOLD	AT 4C	NONE	NONE	NONE			
3/26/93	1100	CA-VWC-6		3			1		1			1		G C	SOIL	
3/26/93	1400	CA-MPA-5.5		3			1		1			1		G C	SOIL	
3/26/93	1500	CA-MPB-5.5		3			1		1			1		G C	SOIL	
														G C	SOIL	
														G C	SOIL	
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														G C	SOIL	

Relinquished by: (Signature) Steven R. Archabal To FED EX. — Date / Time: 3/26/93 1800
Recieved for Laboratory by: (Signature) — Date / Time:

Relinquished by: (Signature) — Date / Time:
Recieved for Laboratory by: (Signature) — Date / Time:

Remarks: Temp 4°C

G - Grab Sample, C - Composite Sample

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files
Federal Express Number: 5909582943
Airbill Number:

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900 • Denver, Colorado
(303) 831-8100

CCRSOIL

ENGINEERING SCIENCE

CHAIN OF CUSTODY RECORD FOR WATER SAMPLES

ES JOB NO.

PROJECT NAME/LOCATION: 4938

FIELD CONTACT:

SAMPLERS NAMES & SIGNATURES

PRESERVATIVES REQUIRED

ANALYSES REQUIRED

TO: SEQUOIA LAB.

DATE	TIME	FIELD SAMPLE IDENTIFIER	E351.2 (TKN)	E365.3 (PHOS)	VCM (CLASS)									REMARKS
1/26/93	1100	(4938.01C) CA-YWG-6	X	X	X			9303E39						REPORT TO:
↓	1400	(4938.02C) CA-MPA-5.5	X	X	X									TOM PAULSON
↓	1500	(4938.3C) CA-MPB-5.5	X	X	X									
		Relinquished By: Eric Vorwerk 3-30-93												

FIELD CUSTODY RELINQUISHED BY: [signature] DATE: 3/29/93 TIME: 1010

SHIPPED VIA: AIRBILL #

ON RECEIPT: CUSTODY SEALS? ____; TEMP: ____ °C

RECEIVED FOR LABORATORY BY: Eric Vorwerk DATE: 3/29/93 TIME: 1415

[signature] 3/30/93